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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

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1a REPORT SECURITY CLASSIFICATION: UNCLASSIFIED
1b RESTRICTIVE MARKINGS:
2a SECURITY CLASSIFICATION AUTHORITY:
2b DECLASSIFICATION / DOWNGRADING SCHEDULE:
3 DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
4 PERFORMING ORGANIZATION REPORT NUMBER(S):
5 MONITORING ORGANIZATION REPORT NUMBER(S):
6a NAME OF PERFORMING ORGANIZATION: Naval Postgraduate School
6b OFFICE SYMBOL (*If applicable*): Code 32
7a NAME OF MONITORING ORGANIZATION: Naval Postgraduate School
6c ADDRESS (*City, State, and ZIP Code*): Monterey, CA 93943-5000
7b ADDRESS (*City, State, and ZIP Code*): Monterey, CA 93943-5000
8a NAME OF FUNDING / SPONSORING ORGANIZATION:
8b OFFICE SYMBOL (*If applicable*):
9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:
8c ADDRESS (*City, State, and ZIP Code*):

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE (*Include Security Classification*)

EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS: A COMPUTER OPTIMIZATION

12 PERSONAL AUTHOR(S): Gensure, John Reynold
13a TYPE OF REPORT: Master's Thesis
13b TIME COVERED: FROM ________ TO ______
14 DATE OF REPORT (*Year, Month, Day*): June 1992
15 PAGE COUNT: 118
16 SUPPLEMENTARY NOTATION: The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Dept. of Defense or the U.S. Govt.

17 COSATI CODES

FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (*Continue on reverse if necessary and identify by block number*): Extended Surfaces, Fins, Heat Sinks

19 ABSTRACT (*Continue on reverse if necessary and identify by block number*)

Heat sinks consisting of individual fins and arrays of fins are used extensively throughout the Navy and industry. The fins serve to increase the surface area through which heat is transferred to the surrounding environment by natural convection. Extended surfaces or fins are commonly found on electronic components ranging from power supplies to transformers. The dissipation and subsequent rejection of potentially destructive self produced heat is an important aspect of electronic equipment design.

Fin design theory is examined starting with the optimization of individual fin dimensions. The insights obtained are utilized in an investigation of the optimal number and spacing of elements in an array of fins. The results are implemented in a computer program written in ADA and compiled for use on IBM compatible machines. The program takes as inputs thermal and physical data and outputs an optimized fin configuration. Menu driven, the program serves to greatly simplify and accelerate the

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS
21 ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL: Kraus, Allan D.
22b TELEPHONE (*Include Area Code*): (408) 646-3378
22c OFFICE SYMBOL: Code 32

DD Form 1473, JUN 86 *Previous editions are obsolete* SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603

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Extended Surface Heat Sinks for Electronic Components: A Computer Optimization

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 1992

ABSTRACT

Heat sinks consisting of individual fins and arrays of fins are used extensively throughout the Navy and industry. The fins serve to increase the surface area thorough which heat is transferred to the surrounding environment by natural convection. Extended surfaces or fins are commonly found on electronic components ranging from power supplies to transformers. The dissipation and subsequent rejection of potentially destructive self produced heat is an important aspect of electronic equipment design.

Fin design theory is examined starting with the optimization of individual fin dimensions. The insights obtained are utilized in an investigation of the optimal number and spacing of elements in an array of fins. The results are implemented in a computer program written in ADA and compiled for use on IBM compatible machines. The program takes as inputs thermal and physical data and outputs an optimized fin configuration. Menu driven, the program is easily employed without any amplifying documentation. The program serves to greatly simplify and accelerate the fin design process and should be an invaluable tool to electronic component designers, especially those with a limited background in heat transfer and fin optimization theory.

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I. INTRODUCTION

Convection is the transfer of energy from a heat source to a cooler surrounding fluid due to the motion of the fluid. The rate of heat transfer by convection, q_c, is governed by Newton's Law of Cooling which is

$$q_c = hA_s(T - T_\infty) \tag{1-1}$$

where h is the coefficient of heat transfer in convection, A_s is the surface area, T is the fin temperature at position x, and T_∞ is the ambient temperature. One method of increasing q_c is to increase h by going from natural to forced convection. Natural convection is a phenomenon in which the fluid motion is induced by differences in buoyancy and density between parcels of fluid at the confining surface and within the bulk of the fluid. Forced convection occurs when the fluid motion is induced or forced by a fan, pump, or blower. Because the addition of a fan or pump may increase operating costs, background noise, and component size, forced convection is often undesirable. An alternative method of increasing q_c is to increase A_s by adding extended surfaces or fins. [Ref. 1:pp. 114-119]

In the design of electronic components, the disadvantages of forced convection often lead to the use of natural convection and fins to dissipate potentially destructive component produced heat. Fin design and optimization in a natural convective environment is the subject of this work.

Fin design theory may be examined by beginning with the single fin problem. The temperature profile differential equation can be developed for arbitrarily shaped fins and subsequently applied to fins of constant cross-sectional area. The temperature distribution, fin tip temperature, heat dissipation, and fin efficiency equations are all derived here and the equations are then applied to the cylindrical spine and rectangular fin, which are two commonly employed fin designs.

Single fin optimization theory is explored for the cylindrical spine and rectangular fin. Two separate situations are examined. First, for a given volume or quantity of material, the fin dimensions can be optimized to maximize the heat transfer rate. Second, for a given heat transfer rate, the fin dimensions can be provided which will minimize the volume of material required.

Multiple fin heat transfer and optimization theories can also be developed for an array of symmetric isothermal rectangular fins. Here too, the equation for the heat dissipation can be derived. This leads to an optimization where the number and spacing of fins can be provided to give the maximum heat transfer rate from a wall of given dimensions. In addition, the number and spacing of fins can be optimized to maximize the heat transfer rate from each fin on a wall of given dimensions.

The single and multiple fin heat transfer and optimization equations are implemented in a computer program written in ADA and compiled for use on IBM compatible machines. The emphasis of the program is on ease of use. The program is menu driven and does not require any amplifying documentation. Knowledge of heat transfer theory is not required. When faced with a fin optimization problem, an electronic component designer is no longer forced to choose between conducting laborious heat transfer calculations or resorting to trial and error.

The computer program is illustrated by means of an actual fin array design problem. The increase in heat transfer rate resulting from a staggering of fin arrays, without any increase in materials or wall placement area, is also demonstrated.

II. SINGLE FIN HEAT TRANSFER THEORY

A. INTRODUCTION

In order to make the mathematical analysis of extended surfaces tractable, Murray [Ref. 2:p. A78] and Gardner [Ref. 3:p. 621] proposed several limiting assumptions. These are:

(1) The heat flow and temperature distribution throughout the fin are independent of time i.e., the heat flow is steady.
(2) The fin material is homogeneous and isotropic.
(3) There are no heat sources in the fin itself.
(4) The heat flow to or from the fin surface at any point is directly proportional to the temperature difference between the surface at that point and the surrounding fluid.
(5) The thermal conductivity of the fin is constant.
(6) The heat transfer coefficient is the same over all the fin surface.
(7) The temperature of the surrounding fluid is uniform.
(8) The temperature of the base of the fin is uniform.
(9) The thickness is so small compared to its height that temperature gradients normal to the surface may be neglected.
(10) The heat transferred through the outermost edge of the fin is negligible compared to that passing through the sides.

These assumptions serve to narrow the scope of the extended surface problem and are applicable in the analysis that follows. [Ref. 3:p. 324]

B. ARBITRARILY SHAPED FINS

1. Temperature Profile Differential Equation

Figure 2-1 is an example of an arbitrarily shaped fin of height b, differential surface area dA_s, and varying cross-sectional area $A(x)$. The Fourier and Newton Laws are used to derive the differential equation for the temperature profile of the fin shown in Figure 2-1. As fins are generally thin, b is assumed to be much greater than r. Although the fin temperature varies with r and x, the radial variation is small and assumed to be negligible. [Ref. 1:pp. 117-118]

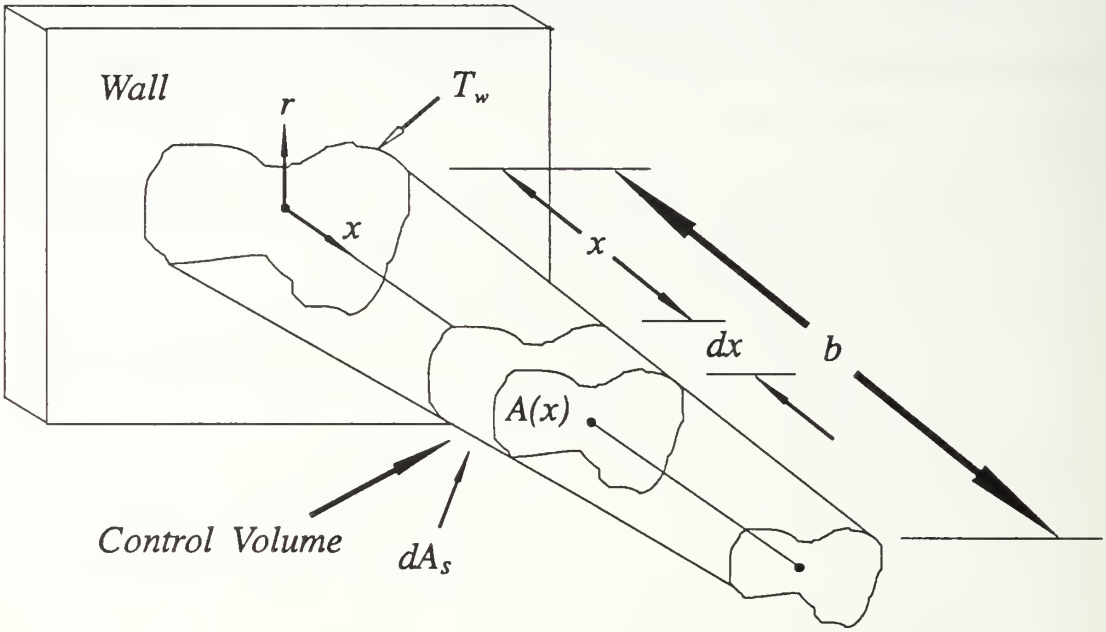


Figure 2-1. Arbitrarily Shaped Fin of Varying Cross-Sectional Area

In Figure 2-1, Heat enters the control volume by conduction at a rate of $q(x)$ and exits at a rate of $q(x+dx)$. Heat is dissipated by convection through dA_s at a rate of dq_c. [Ref. 1:p. 118]

Ignoring radiation and assuming no internal heat generation, the heat balance energy equation for the control volume can be written as

$$q(x) = q(x+dx) + dq_c \tag{2-1}$$

Substituting for $q(x+dx)$

$$q(x) = \left(q(x) + \frac{dq(x)}{dx} dx \right) + dq_c \tag{2-2}$$

and simplifying yields

$$-\frac{dq(x)}{dx}dx = dq_c \tag{2-3}$$

Fourier's Law can be expressed as

$$q(x) = -kA(x)\frac{dT}{dx} \tag{2-4}$$

where k is the thermal conductivity of the fin material and dT/dx is the temperature gradient. Differentiating Equation 2-4 with respect to x gives

$$\frac{dq(x)}{dx} = -k\frac{d}{dx}\left(A(x)\frac{dT}{dx}\right) \tag{2-5}$$

Newton's Law of Cooling can be written as

$$dq_c = hdA_s(T - T_\infty) \tag{2-6}$$

Substituting Equations 2-5 and 2-6 into Equation 2-3 gives

$$k\frac{d}{dx}\left(A(x)\frac{dT}{dx}\right)dx = hdA_s(T - T_\infty) \tag{2-7}$$

Then, differentiating and dividing both sides by kdx provides

$$\frac{dA(x)}{dx}\frac{dT}{dx} + A(x)\frac{d^2T}{dx^2} = \frac{h}{k}\frac{dA_s}{dx}(T - T_\infty) \tag{2-8}$$

so that a simplification then gives

$$\frac{d^2T}{dx^2} + \frac{1}{A(x)}\frac{dA(x)}{dx}\frac{dT}{dx} - \frac{h}{kA(x)}\frac{dA_s}{dx}(T - T_\infty) = 0 \tag{2-9}$$

Equation 2-9 is the temperature profile differential equation for an arbitrarily shaped fin of varying cross-sectional area. [Ref. 1:pp. 118-119]

2. Temperature Distribution Equation

A general solution to Equation 2-9, is found for a fin with constant cross-sectional area, A. Uniform cross-sectional area means that $A(x) = A$ (a constant) and permits the simplification

$$\frac{dA(x)}{dx} = 0 \tag{2-10}$$

and with this in Equation 2-9, the result is

$$\frac{d^2T}{dx^2} - \frac{h}{kA}\frac{dA_s}{dx}(T - T_\infty) = 0 \tag{2-11}$$

If the surface area is expressed in terms of the perimeter, P

$$dA_s = Pdx \tag{2-12}$$

a substitution into Equation 2-11 yields

$$\frac{d^2T}{dx^2} - \frac{hP}{kA}(T - T_\infty) = 0 \tag{2-13}$$

and if a change of variables

$$\theta \equiv T - T_\infty \tag{2-14}$$

is made, then

$$T = \theta + T_\infty \tag{2-15}$$

$$\frac{dT}{dx} = \frac{d\theta}{dx} \tag{2-16}$$

and

$$\frac{d^2T}{dx^2} = \frac{d^2\theta}{dx^2} \tag{2-17}$$

Use of these permits Equation 2-13 to be written as

$$\frac{d^2\theta}{dx^2} - \frac{hP}{kA}\theta = 0 \tag{2-18}$$

and if the parameter, m, is introduced

$$m \equiv \sqrt{\frac{hP}{kA}} \tag{2-19}$$

then Equation 2-18 can be written as

$$\frac{d^2\theta}{dx^2} - m^2\theta = 0 \tag{2-20}$$

The general solution to Equation 2-20 is

$$\theta = C_1 \cosh(mx) + C_2 \sinh(mx) \tag{2-21}$$

where the arbitrary constants, C_1 and C_2, are evaluated from the boundary conditions

- At position $x = 0$, $T = T_w$ and $\theta_w = T_w - T_\infty$
- At position $x = b$, $\frac{dT}{dx} = 0$ and $\frac{d\theta}{dx} = 0$

where T_w is the wall temperature. The second boundary condition is based on the earlier assumption that b is much greater than r so that the surface area at the fin tip is very small and that the heat dissipated at the tip is negligible. The heat convected away from the surface area at the tip of the fin is considered negligible. Applying the first boundary condition to Equation 2-21 yields

$$\theta_w = C_1 \cdot 1 + C_2 \cdot 0 \tag{2-22}$$

so that

$$C_1 = \theta_w \tag{2-23}$$

Then, a differentiation of Equation 2-21 gives

$$\frac{d\theta}{dx} = \theta_w m \sinh(mx) + C_2 m \cosh(mx) \tag{2-24}$$

so that employment of the second boundary condition provides

$$0 = \theta_w m \sinh(mb) + C_2 m \cosh(mb) \tag{2-25}$$

and hence

$$C_2 = -\frac{\theta_w \sinh(mb)}{\cosh(mb)} \tag{2-26}$$

After substitution for C_1 and C_2, Equation 2-21 becomes

$$\frac{\theta}{\theta_w} = \frac{\cosh(mb)\cosh(mx) - \sinh(mb)\sinh(mx)}{\cosh(mb)} \tag{2 -27}$$

Using a hyperbolic function identity in Equation 2-27 allows the representation

$$\frac{\theta}{\theta_w} = \frac{\cosh\left[mb\left(1-\frac{x}{b}\right)\right]}{\cosh(mb)} \tag{2-28}$$

and returning to $\theta_w = T_w - T_\infty$

$$T = T_\infty + \frac{(T_w - T_\infty)\cosh\left[mb\left(1-\frac{x}{b}\right)\right]}{\cosh(mb)} \tag{2-29}$$

Equation 2-29 gives the temperature profile for a fin of constant cross-sectional area. The temperature at any position x along the fin can be calculated using Equation 2-29. [Ref. 1:pp. 120-123]

3. Fin Tip Temperature Equation

Often, a value of interest is the temperature at the tip of the fin, T_{tip}. Substituting $x = b$ into Equation 2-29 gives

$$T_{tip} = T_\infty + \frac{(T_w - T_\infty)}{\cosh(mb)} \tag{2-30}$$

Equation 2-30 is the equation for the fin tip temperature for a fin of constant cross-sectional area. [Ref. 1:pp. 145-146]

4. Heat Dissipation Equation

The heat dissipation equation for a fin of constant cross-sectional area is derived using Fourier's Law and Equation 2-27. From Fourier's Law,

$$q = -kA\frac{dT}{dx}\bigg|_{x=0} = -kA\frac{d\theta}{dx}\bigg|_{x=0} \tag{2-31}$$

Differentiation of Equation 2-27 yields

$$\frac{d\theta}{dx} = \frac{\theta_w\left[m\cosh(mb)\sinh(mx) - m\sinh(mb)\cosh(mx)\right]}{\cosh(mb)} \tag{2-32}$$

and this may be put into Equation 2-31 to obtain

$$q = -\frac{kA\theta_w\left[m\cosh(mb)\sinh(mx) - m\sinh(mb)\cosh(mx)\right]}{\cosh(mb)}\Bigg|_{x=0} \tag{2-33}$$

A simplification then yields

$$q = \frac{kA\theta_w\left[m\sinh(mb)\right]}{\cosh(mb)} \tag{2-34}$$

and substituting for θ_w gives

$$q = kAm(T_w - T_\infty)\tanh(mb) \tag{2-35}$$

Equation 2-35 is the heat dissipation equation for a fin of constant cross-sectional area. [Ref. 1:p. 123]

5. Fin Efficiency

A common parameter employed in the design of finned surfaces is the fin efficiency, η. The definition of η is the actual heat dissipated by the fin divided by that which would be dissipated if the fin operated throughout at the wall temperature. If Equation 2-35, which gives the actual dissipation, is divided by Newton's Law of Cooling, which gives the ideal dissipation, the result is

$$\eta = \frac{kAm(T_w - T_\infty)\tanh(mb)}{hA_s(T_w - T_\infty)} \tag{2-36}$$

Hence

$$\eta = \frac{kAm\tanh(mb)}{hA_s} \tag{2-37}$$

and

$$\eta = \frac{kAm^2\tanh(mb)}{mhA_s} \tag{2-38}$$

and with $m^2 = hP/kA$ by Equation 2-19

$$\eta = \frac{kAhP\tanh(mb)}{kAmhA_s} \tag{2-39}$$

Thus

$$\eta = \frac{P\tanh(mb)}{mA_s} \tag{2-40}$$

But $A_s = Pb$, and this simplification gives the final expression for the fin of constant cross-section.

$$\eta = \frac{\tanh(mb)}{mb} \tag{2-41}$$

Equation 2-41 provides the efficiency of a fin with constant cross-sectional area. [Ref. 1:p. 125]

C. SPECIFIC FIN CONFIGURATIONS

1. Cylindrical Spine

As shown in Figure 2-2, a cylindrical spine is essentially a bar of height b and diameter d attached to the surface to be cooled. As the fin has a constant cross-sectional area, the equations derived in the previous section apply to the cylindrical spine. [Ref. 1:p. 120]

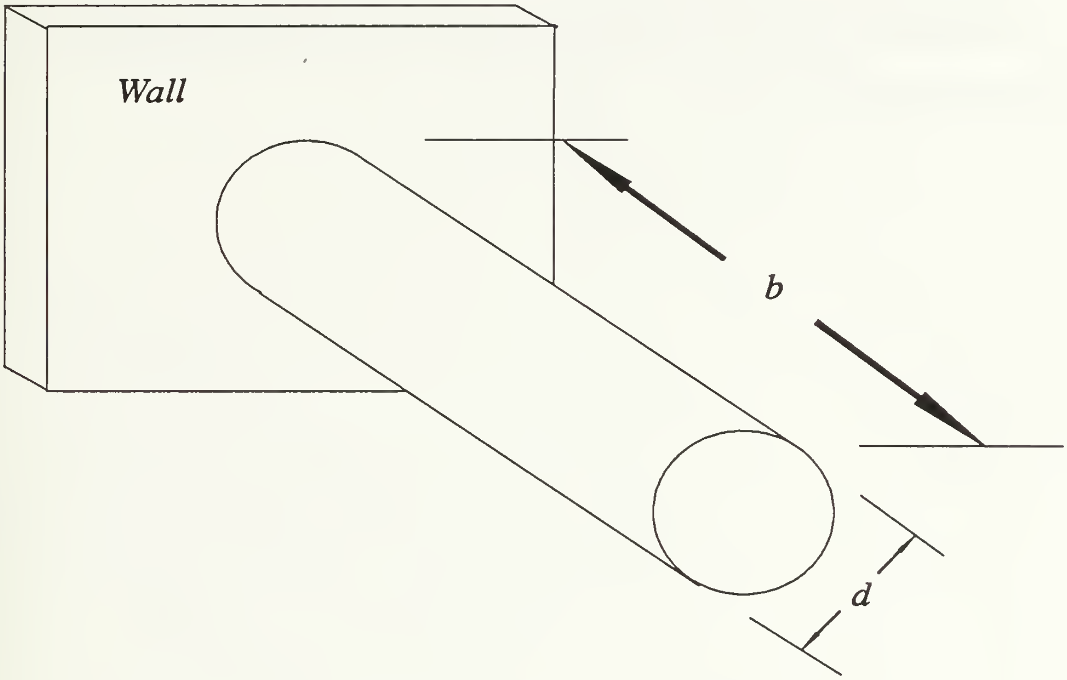


Figure 2-2. Cylindrical Spine

For the cylindrical spine, the perimeter and area are written as

$$P = \pi d \tag{2-42}$$

and

$$A = \frac{\pi d^2}{4} \tag{2-43}$$

Hence, Equation 2-19 becomes

$$m = \sqrt{\frac{4h}{kd}} \tag{2-44}$$

2. Longitudinal Fin of Rectangular Profile

A commonly encountered fin configuration is that of the longitudinal fin of rectangular profile. Figure 2-3 is an example of a rectangular fin of height *b*, length *L*, and width δ. The equations derived for fins of constant cross-sectional area are applicable to the rectangular fin configuration. [Ref. 1:p. 120]

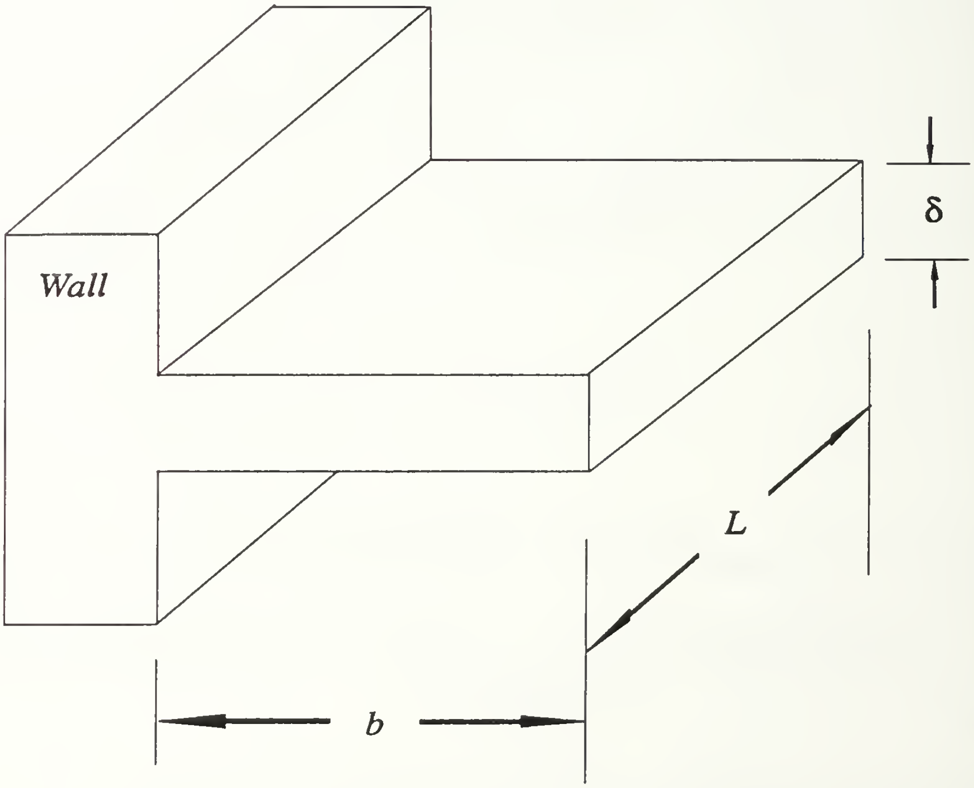


Figure 2-3. Rectangular Fin

For the longitudinal fin of rectangular profile, the perimeter and area are

$$P = 2\delta + 2L \tag{2-45}$$

and

$$A = L\delta \tag{2-46}$$

As rectangular fins are traditionally thin, the following simplification is made [Ref. 1:p. 137].

$$P \cong 2L \tag{2-47}$$

Substituting Equations 2-46 and 2-47 into Equation 2-19 gives

$$m = \sqrt{\frac{2h}{k\delta}} \tag{2-48}$$

III. SINGLE FIN OPTIMIZATION THEORY

A. INTRODUCTION

Single fin optimization theory can be divided into two categories. In the first category the fin shape is known. Two commonly employed fin shapes, the cylindrical spine and the rectangular fin, may be examined from two different perspectives. Either the dimensions of the fin are optimized to yield the maximum heat transfer rate from a given volume or, for a given heat transfer rate, the fin dimensions are optimized to minimize the required volume of material. The second category is based on the determination of an optimal fin shape. Fin shapes are found which minimize the volume of material required to obtain a given heat transfer rate. Curved fins are commonly produced in the shape optimization problem. As curved fins are difficult and expensive to manufacture, the shape optimization problem will not be addressed. [Ref. 5:p. 155]

B. CYLINDRICAL SPINE

1. Maximum Heat Transfer for a Given Volume

Substituting Equations 2-43 and 2-44 into Equation 2-35 yields

$$q = k\frac{\pi d^2}{4}\sqrt{\frac{4h}{kd}}(T_w - T_\infty)\tanh\left(\sqrt{\frac{4h}{kd}}b\right) \tag{3-1}$$

If

$$\beta = b\sqrt{\frac{4h}{kd}} \tag{3-2}$$

then

$$q = \left[\frac{k\pi d^2(T_w - T_\infty)}{4b}\right]\beta\tanh(\beta) \tag{3-3}$$

and for a cylinder of volume V

$$V = \frac{\pi d^2 b}{4} \tag{3-4}$$

and

$$b = \frac{4V}{\pi d^2} \tag{3-5}$$

or

$$d = \sqrt{\frac{4V}{\pi b}} \tag{3-6}$$

Substituting Equation 3-5 into Equation 3-3 yields

$$q = \left[\frac{k\pi^2 d^4(T_w - T_\infty)}{16V}\right]\beta\tanh(\beta) \tag{3-7}$$

Then, taking the derivative with respect to d, simplifying, and setting it equal to zero leads to the following transcendental equation.

$$10\beta = 3\sinh(2\beta) \tag{3-8}$$

with a solution which can be determined by trial and error

$$\beta = 0.9193 \tag{3-9}$$

Substitution of this value of β into Equation 3-2 produces

$$0.9193 = b\sqrt{\frac{4h}{kd}} \tag{3-10}$$

Expressing b by Equation 3-5 gives

$$0.9193 = \frac{4V}{\pi d^2}\sqrt{\frac{4h}{kd}} \qquad (3\text{-}11)$$

Hence, the optimized value for the diameter, d, is

$$d_{opt} = 1.5031\left(\frac{hV^2}{k}\right)^{1/5} \qquad (3\text{-}12)$$

and substitution of Equation 3-6 into Equation 3-10 yields

$$0.9193 = b\sqrt{\frac{4h}{k\left(\frac{4V}{\pi b}\right)^{1/2}}} \qquad (3\text{-}13)$$

Thus, the optimized value for the height, b, is

$$b_{opt} = 0.5636\left(\frac{Vk^2}{h^2}\right)^{1/5} \qquad (3\text{-}14)$$

Equations 3-12 and 3-14 specify the optimal dimensions of a cylindrical spine to achieve the maximum heat transfer rate for a given volume. [Ref. 5:p. 158]

2. Minimum Volume for a Given Heat Transfer

Solve Equation 3-10 for b

$$b = 0.9193\sqrt{\frac{kd}{4h}} \qquad (3\text{-}15)$$

and then substitute Equations 3-15 and 3-9 into Equation 3-3 to obtain

$$q = \left[\frac{k\pi d^2(T_w - T_\infty)}{4(0.9193)\sqrt{\frac{kd}{4h}}}\right]0.9193\tanh(0.9193) \qquad (3\text{-}16)$$

Hence

$$d_{opt} = 0.9165\left(\frac{q^2}{hk(T_w - T_\infty)^2}\right)^{1/3} \tag{3-17}$$

The solution of the transcendental, Equation 3-10, is for *d*

$$d = \frac{4hb^2}{k(0.9193)^2} \tag{3-18}$$

and substituting Equations 3-18 and 3-9 into Equation 3-3 yields

$$q = \left[\frac{16h^2b^4k\pi(T_w - T_\infty)}{4bk^2(0.9193)^4}\right]0.9193\tanh(0.9193) \tag{3-19}$$

Thus

$$b_{opt} = 0.4400\left(\frac{qk}{h^2(T_w - T_\infty)}\right)^{1/3} \tag{3-20}$$

Equations 3-17 and 3-20 specify the optimal dimensions of a cylindrical spine to achieve the minimum volume for a given heat transfer rate. [Ref. 5:p. 158]

C. RECTANGULAR FIN

1. Maximum Heat Transfer for a Given Volume and Length

Substituting Equations 2-46 and 2-48 into Equation 2-35 gives

$$q = k\delta L\sqrt{\frac{2h}{k\delta}}(T_w - T_\infty)\tanh\left(b\sqrt{\frac{2h}{k\delta}}\right) \tag{3-21}$$

For a rectangular fin

$$V = \delta L b \tag{3-22}$$

or

$$b = \frac{V}{\delta L} \tag{3-23}$$

and

$$\delta = \frac{V}{bL} \tag{3-24}$$

Substituting Equation 3-23 into Equation 3-21 yields

$$q = k\delta L\sqrt{\frac{2h}{k\delta}}(T_w - T_\infty)\tanh\left(\frac{V}{\delta L}\sqrt{\frac{2h}{k\delta}}\right) \tag{3-25}$$

and, once more, making a change of variables

$$U = \frac{V}{L}\sqrt{\frac{2h}{k\delta^3}} \tag{3-26}$$

gives

$$q = k\delta L\sqrt{\frac{2h}{k\delta}}(T_w - T_\infty)\tanh(U) \tag{3-27}$$

Taking the derivative with respect to δ, simplifying, and setting the result equal to zero, yields the transcendental equation

$$6U = \sinh(2U) \tag{3-28}$$

A trial and error solution gives

$$U = 1.4192 \tag{3-29}$$

and substituting this result into Equation 3-26 gives

$$1.4192 = \frac{V}{L}\sqrt{\frac{2h}{k\delta^3}} \tag{3-30}$$

This shows that the optimized value for the width, δ, is

$$\delta_{opt} = 0.9977\left[\frac{V^2h}{L^2k}\right]^{1/3} \tag{3-31}$$

Substituting Equation 3-24 into Equation 3-30 yields

$$1.4192 = \frac{V}{L}\sqrt{\frac{2h}{k\left(\frac{V}{bL}\right)^3}} \tag{3-32}$$

and

$$b_{opt} = 1.0023\left[\frac{Vk}{Lh}\right]^{1/3} \tag{3-33}$$

Equations 3-31 and 3-33 specify the optimal dimensions of a rectangular fin to achieve the maximum heat transfer rate for a given volume and length. [Ref. 5:p. 156]

2. Minimum Volume for a Given Heat Transfer and Length

Substituting Equation 3-29 into Equation 3-27 gives

$$q = k\delta L\sqrt{\frac{2h}{k\delta}}(T_w - T_\infty)\tanh(1.4192) \tag{3-34}$$

and from this the optimum δ is obtained

$$\delta_{opt} = \frac{0.6321}{hk}\left(\frac{q}{L(T_w - T_\infty)}\right)^2 \tag{3-35}$$

Then, substituting Equation 3-24 into Equation 3-35 yields

$$\frac{V}{bL} = \frac{0.6321}{hk}\left(\frac{q}{L(T_w - T_\infty)}\right)^2 \tag{3-36}$$

and solving Equation 3-33 for V provides

$$V = \frac{b^3 L h}{(1.0023)^3 k} \tag{3-37}$$

Then, substituting this result into Equation 3-36 produces

$$\frac{b^3 L h}{(1.0023)^3 k b L} = \frac{0.6321}{hk} \left(\frac{q}{L(T_w - T_\infty)} \right)^2 \tag{3-38}$$

and the optimum value of the fin height, b is

$$b_{opt} = 0.7978 \frac{q}{Lh(T_w - T_\infty)} \tag{3-39}$$

Equations 3-35 and 3-39 specify the optimal dimensions of a rectangular fin to achieve the minimum volume for a given heat transfer rate and length. [Ref. 5:p. 156]

IV. MULTIPLE FIN HEAT TRANSFER THEORY

A. INTRODUCTION

In their 1984 landmark paper, Bar-Cohen and Rohsenow described the heat transfer and optimization equations for an array of rectangular fins. However, they did not provide a design procedure with which to use their data to formulate optimum arrays. [Ref. 6:pp. 116-123]

B. ARRAY OF RECTANGULAR FINS

1. Heat Dissipation Equation

In Figure 4-1, adjacent fins form a channel. The channel Rayleigh number, *Ra*' is defined as

$$Ra' \equiv \frac{\rho^2 g \beta c_p z^4 (T_w - T_\infty)}{\mu L k_f} \tag{4-1}$$

where

- ρ = density of the surrounding fluid, kg/m^3
- g = gravitational acceleration, m/s^2
- β = volumetric coefficient of thermal expansion, 1/°K
- c_p = specific heat of the surrounding fluid, J/kg°C
- z = clear spacing, m
- T_w = wall temperature, °C
- T_∞ = ambient temperature, °C
- μ = dynamic viscosity of the surrounding fluid, kg/m•s

- L = fin length, m
- k_f = thermal conductivity of the surrounding fluid, W/m°C

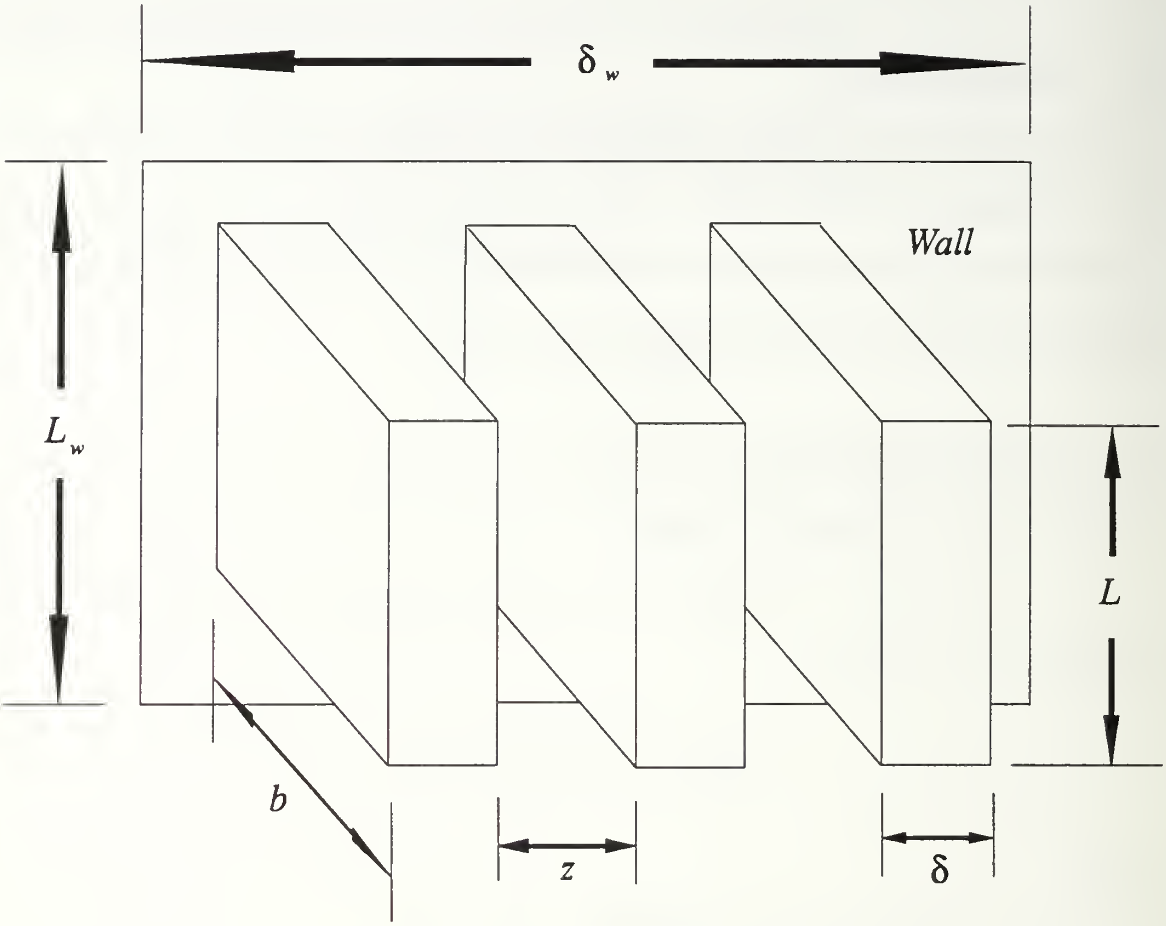


Figure 4-1. Array of Rectangular Fins

The volumetric coefficient of thermal expansion is

$$\beta = \frac{1}{T_{avg} + 460°\text{R}} \tag{4-2}$$

or, in SI units

$$\beta = \frac{1}{T_{avg} + 273.15\text{K}} \tag{4-3}$$

where

$$T_{avg} = \frac{T_w + T_\infty}{2} \qquad (4\text{-}4)$$

The dynamic viscosity is

$$\mu = \frac{\nu\rho}{g_c} \qquad (4\text{-}5)$$

where ν is the kinematic viscosity of the surrounding fluid and

$$g_c = 32.2 \frac{\text{lbm} \cdot \text{ft}}{\text{lbf} \cdot \text{s}^2} \qquad (4\text{-}6)$$

or, in SI units

$$g_c = 1.0 \frac{\text{kg} \cdot \text{m}}{\text{N} \cdot \text{s}^2} \qquad (4\text{-}7)$$

If the fins are assumed to be symmetric and isothermal

$$Nu_0 = \left[\frac{576}{(Ra')^2} + \frac{2.873}{\sqrt{Ra'}} \right]^{-1/2} \qquad (4.8)$$

where Nu_0 is the channel Nusselt number. Thus, the heat transfer coefficient is for n fins attached to the wall

$$h = \frac{nu_0 k_f}{z} \qquad (4\text{-}9)$$

For a rectangular fin, the parameter m is given by Equation 2-48. The fin efficiency, η, is given by Equation 2-41. The surface area of the wall that is open for heat transfer, A_w, is

$$A_w = (L_w \delta_w) - (nL\delta) \qquad (4\text{-}10)$$

and the combined heat transfer area for all fins, A_{fins}, is

$$A_{fins} = n(2bL) \qquad (4\text{-}11)$$

Hence, the total area available for heat transfer, A_{total}, is

$$A_{total} = A_w + \left(\eta A_{fins}\right) \tag{4-12}$$

and according to Newton's Law of Cooling

$$q = hA_{total}\left(T_w - T_\infty\right) \tag{4-13}$$

Equation 4-13 is the heat dissipation equation for an array of symmetric, isothermal rectangular fins. [Ref. 6:pp. 116-119]

V. MULTIPLE FIN OPTIMIZATION THEORY

A. ARRAY OF RECTANGULAR FINS

1. Maximum Heat Transfer for a Given Wall Area

In an array of symmetric, isothermal rectangular fins, the heat transfer rate of each fin decreases as fin spacing decreases. Yet, a reduction in fin spacing allows for a greater number of fins to be placed on a wall of given dimensions. An optimal fin spacing exists which maximizes the heat transfer rate for a given wall area. [Ref. 6:p. 120]

As the wall will be fully populated with fins to maximize q, A_{fins} is assumed to be much greater than A_w. Replacing A_{total} in Equation 4-13 with A_{fins},

$$q = hA_{fins}(T_w - T_\infty) \tag{5-1}$$

and substitution of this into Equations 4-9 and 4-11 gives

$$q = \frac{Nu_0 k_f}{z} N(2bL)(T_w - T_\infty) \tag{5-2}$$

To fully populate the wall with fins

$$N = \frac{\delta_w}{(z+\delta)} \tag{5-3}$$

The value obtained for N from Equation 5-3 must be truncated to produce an integral number of fins. Substitution of Equations 4-8 and 5-3 into Equation 5-2 gives

$$q=\frac{\left[\frac{576}{(Ra')^2}+\frac{2.873}{\sqrt{Ra'}}\right]^{-1/2}k_f\delta_w(2bL)(T_w-T_\infty)}{z(z+\delta)} \tag{5-4}$$

and then making a change of variables,

$$P\equiv\frac{Ra'}{z^4}=\frac{\rho^2 g\beta c_p(T_w-T_\infty)}{\mu L k_f} \tag{5-5}$$

one obtains

$$q=\frac{\left[\frac{576}{P^2z^8}+\frac{2.873}{\sqrt{P}z^2}\right]^{-1/2}k_f\delta_w(2bL)(T_w-T_\infty)}{z(z+\delta)} \tag{5-6}$$

or

$$\frac{q}{2k_f\delta_w bL(T_w-T_\infty)}=\frac{1}{z(z+\delta)\left[\frac{576}{P^2z^8}+\frac{2.873}{\sqrt{P}z^2}\right]^{1/2}} \tag{5-7}$$

Taking the derivative dq/dz, simplifying, and then setting the result equal to zero gives

$$2z+3\delta-0.005P^{3/2}z^7=0 \tag{5-8}$$

If the width is assumed to be negligible,

$$z_{opt}=\frac{2.714}{P^{1/4}} \tag{5-9}$$

Equation 5-9 gives the optimal fin spacing to maximize the heat transfer rate for a wall of given dimensions. [Ref. 6:p. 120]

2. Maximum Heat Transfer from Each Fin

It is often desired to maximize the heat transfer rate from each fin in an array of symmetric, isothermal rectangular fins. Although an infinite fin spacing is theoretically required, setting Nu_0 equal to 99% of the isolated fin value leads to

$$z_{max} = \frac{4.64}{P^{1/4}} \tag{5-10}$$

Equation 5-10 gives the optimal fin spacing to maximize the heat transfer rate from each fin on a wall of given dimensions. Substituting the z_{max} of Equation 5-3 provides the value for the maximum number of fins. [Ref. 6:p. 120]

The value of z_{max} is approximately double that of the boundary layer thicknesses along each of the surfaces at the channel exit. The value z_{opt} coincides with approximately 1.2 boundary layer thicknesses. [Ref. 6:p. 120]

VI. COMPUTER PROGRAM DEMONSTRATION

A. INTRODUCTION

To provide a demonstration of the computer program, a fin array design example involving a wall of given dimensions populated by two different arrangements of rectangular fins, is analyzed and the results are compared.

B. SINGLE NON-STAGGERED FIN ARRAY

In the first arrangement, the wall is populated by a single, non-staggered fin array. The dimensions of the array are shown in Figure 6-1. The computer program will optimize fin spacing to maximize the array's heat transfer rate.

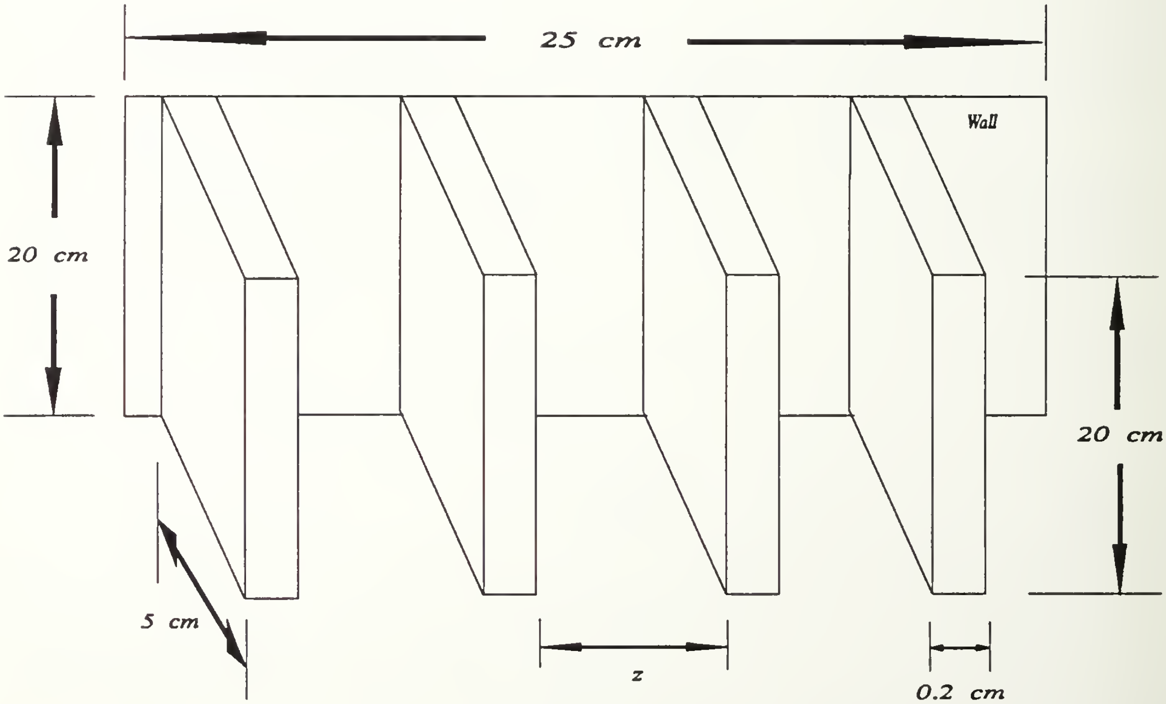
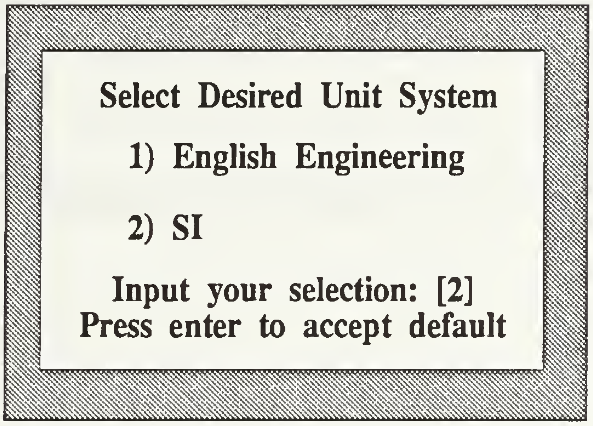


Figure 6-1. Single Non-Staggered Fin Array

The program is initiated by the typing the following command at the DOS prompt.

```
C:\>finopt ↵
```

After the introduction and continuation screens, Figure 6-2 is presented.



Select Desired Unit System

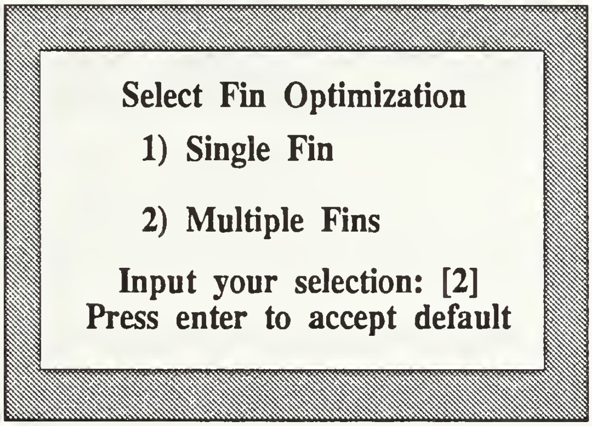
1) English Engineering

2) SI

Input your selection: [2]
Press enter to accept default

Figure 6-2. Unit System Menu

As the dimensions in Figure 6-1 are in centimeters, the enter key (↵) is pressed to select the SI unit system. Figure 6-3 is shown on the screen.



Select Fin Optimization

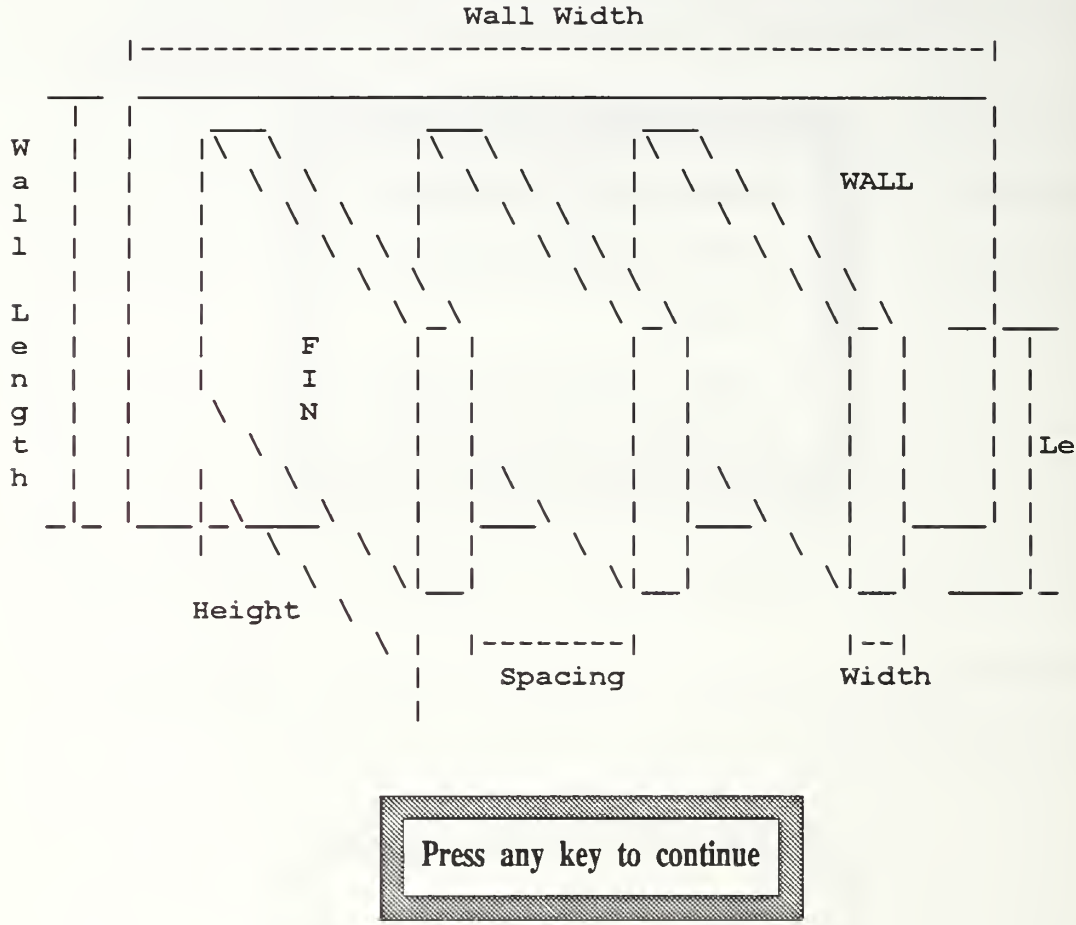
1) Single Fin

2) Multiple Fins

Input your selection: [2]
Press enter to accept default

Figure 6-3. Fin Optimization Menu

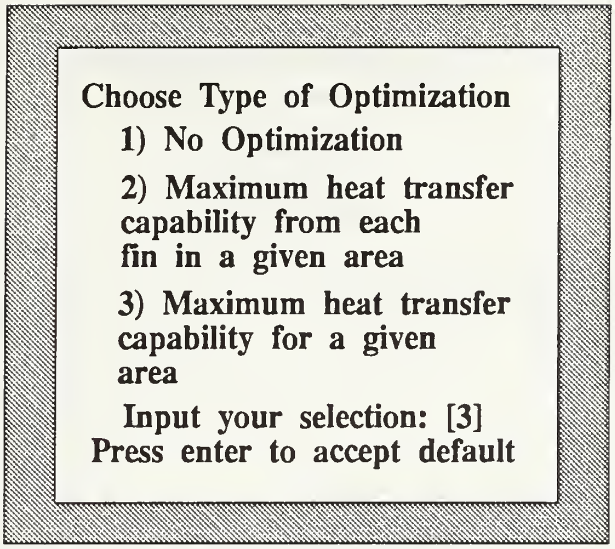
Enter is pressed to select the multiple fin problem. The drawing in Figure 6-4 is then shown on the screen.



Press any key to continue

Figure 6-4. Multiple Fin Drawing

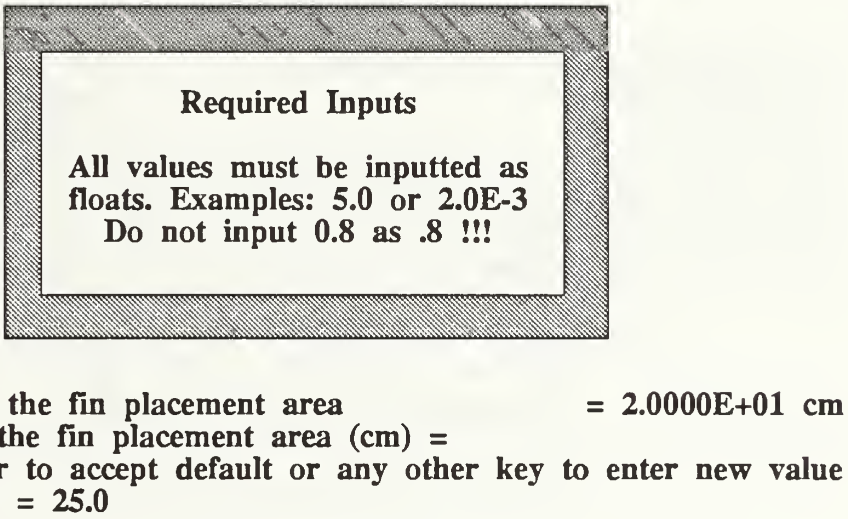
Figure 6-4 graphically shows the nomenclature for the parameters that will be requested by the program so that the optimization and heat transfer calculations can be instituted. After pressing any key, the menu in Figure 6-5 is displayed. Enter is pressed to choose the third selection listed in the menu.



```
Choose Type of Optimization
   1) No Optimization
   2) Maximum heat transfer
   capability from each
   fin in a given area
   3) Maximum heat transfer
   capability for a given
   area
   Input your selection: [3]
 Press enter to accept default
```

Figure 6-5. Type of Optimization Menu

Figure 6-6 illustrates the format used for the input of the parameters needed by the optimization and heat transfer equations.



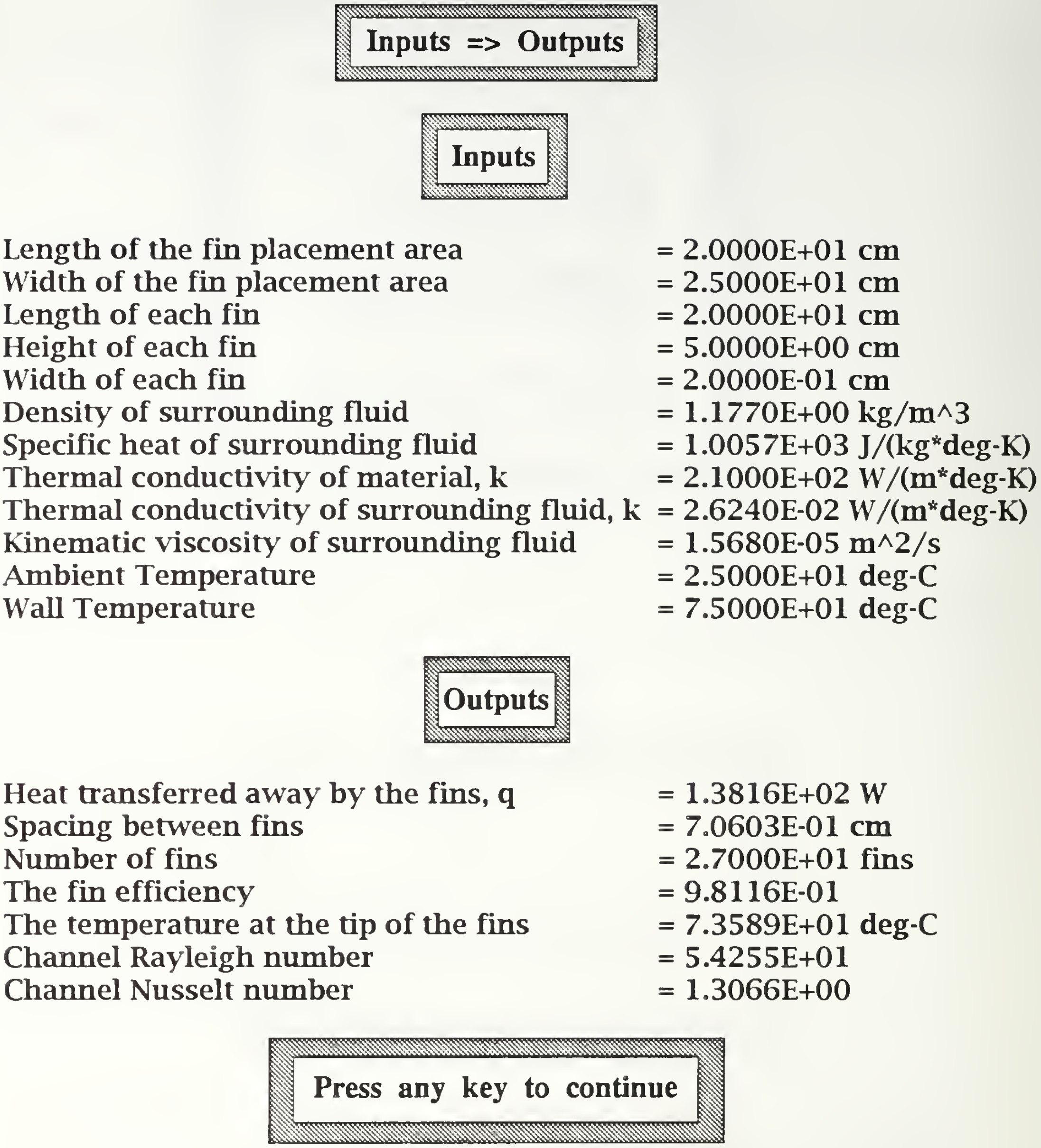
```
Required Inputs

All values must be inputted as
floats. Examples: 5.0 or 2.0E-3
Do not input 0.8 as .8 !!!

Length of the fin placement area              = 2.0000E+01 cm
Width of the fin placement area (cm) =
Press enter to accept default or any other key to enter new value
New value = 25.0
```

Figure 6-6. Request for Inputs

Once the user has supplied the required inputs, the input-output summary screens in Figure 6-7 are presented.



```
Inputs => Outputs

Inputs

Length of the fin placement area                   = 2.0000E+01 cm
Width of the fin placement area                    = 2.5000E+01 cm
Length of each fin                                 = 2.0000E+01 cm
Height of each fin                                 = 5.0000E+00 cm
Width of each fin                                  = 2.0000E-01 cm
Density of surrounding fluid                       = 1.1770E+00 kg/m^3
Specific heat of surrounding fluid                 = 1.0057E+03 J/(kg*deg-K)
Thermal conductivity of material, k                = 2.1000E+02 W/(m*deg-K)
Thermal conductivity of surrounding fluid, k       = 2.6240E-02 W/(m*deg-K)
Kinematic viscosity of surrounding fluid           = 1.5680E-05 m^2/s
Ambient Temperature                                = 2.5000E+01 deg-C
Wall Temperature                                   = 7.5000E+01 deg-C

Outputs

Heat transferred away by the fins, q               = 1.3816E+02 W
Spacing between fins                               = 7.0603E-01 cm
Number of fins                                     = 2.7000E+01 fins
The fin efficiency                                 = 9.8116E-01
The temperature at the tip of the fins             = 7.3589E+01 deg-C
Channel Rayleigh number                            = 5.4255E+01
Channel Nusselt number                             = 1.3066E+00

Press any key to continue
```

Figure 6-7. Input-Output Summary

The user can print the summary information in Figure 6-7 by performing a DOS screen dump, simultaneously pressing the Shift and Print Screen keys. The information can be imported into a word processor for editing by running the program under Microsoft Windows and using its clipboard screen capture functions [Ref. 7:pp. 248-250]. Pressing any key will produce the drawing in Figure 6-8.

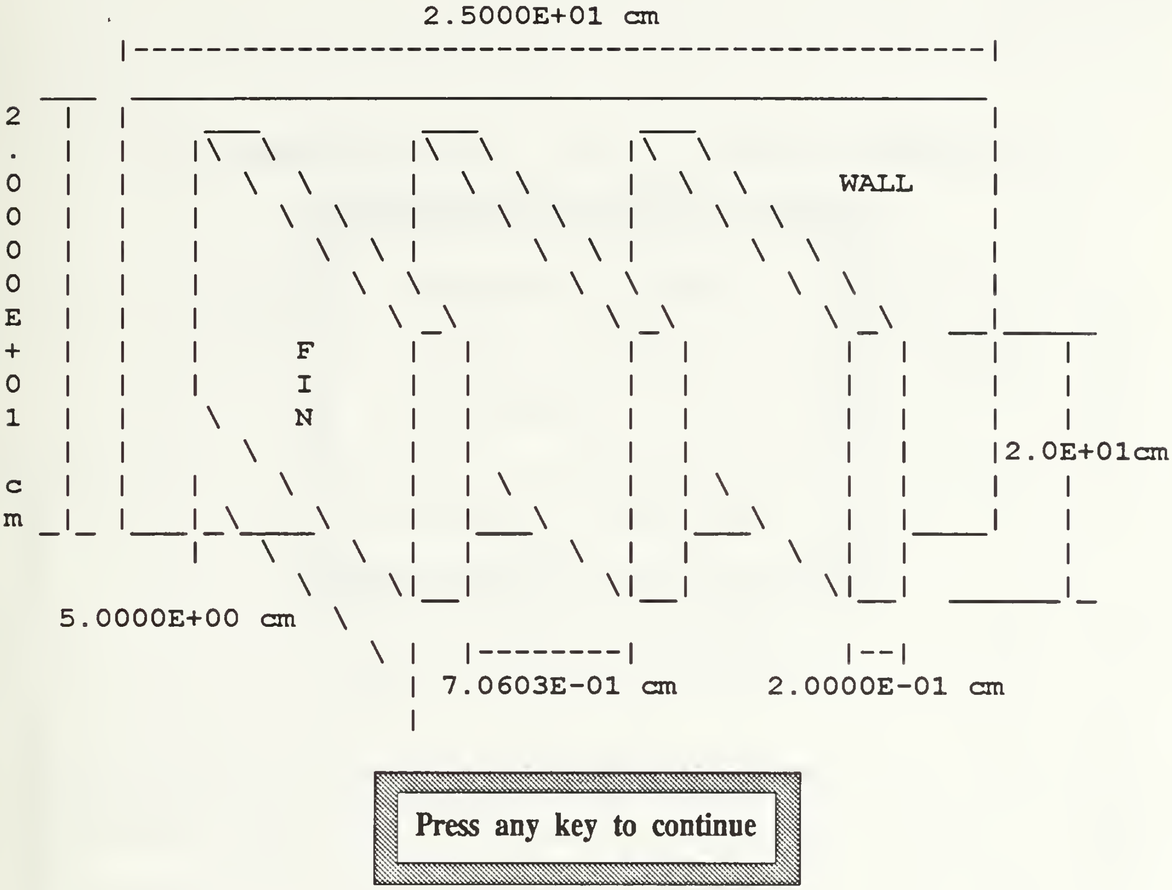


Figure 6-8. Input-Output Summary Drawing

The drawing in Figure 6-8 graphically displays the outputs of the optimization calculations.

C. TWO STAGGERED FIN ARRAYS

In the second arrangement, the wall is populated by two staggered fin arrays. The dimensions of the arrays are shown in Figure 6-9. Each array will be dealt with separately. The heat transfer rate for a single array will be calculated and doubled to find the total heat transfer rate for the wall of given dimensions.

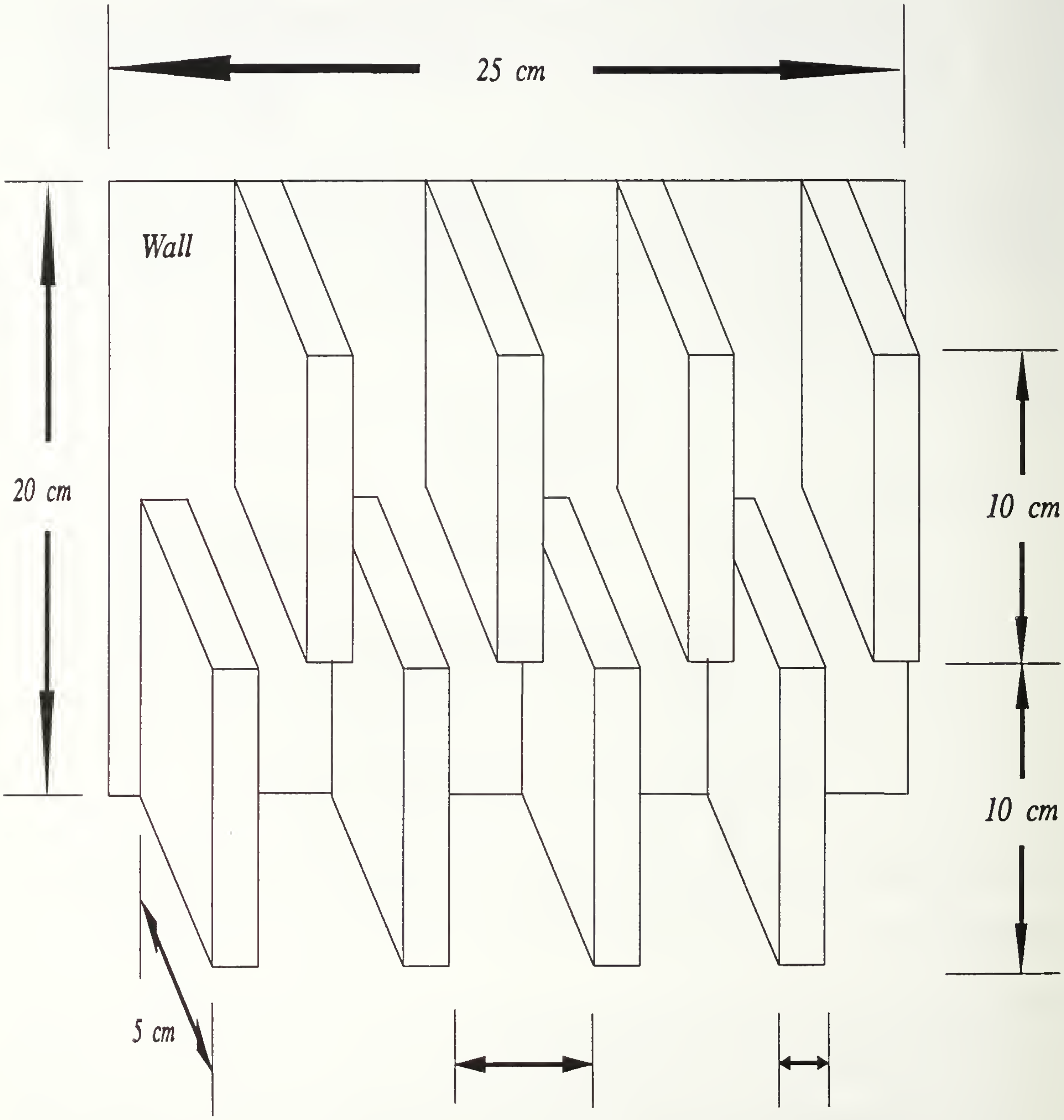
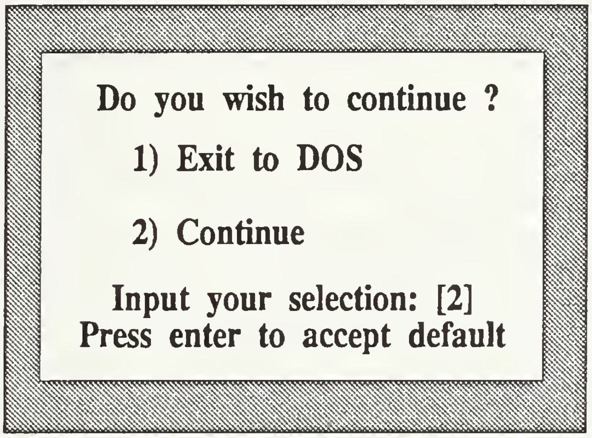


Figure 6-9. Two Staggered Fin Arrays

1. Same Spacing and Number of Fins

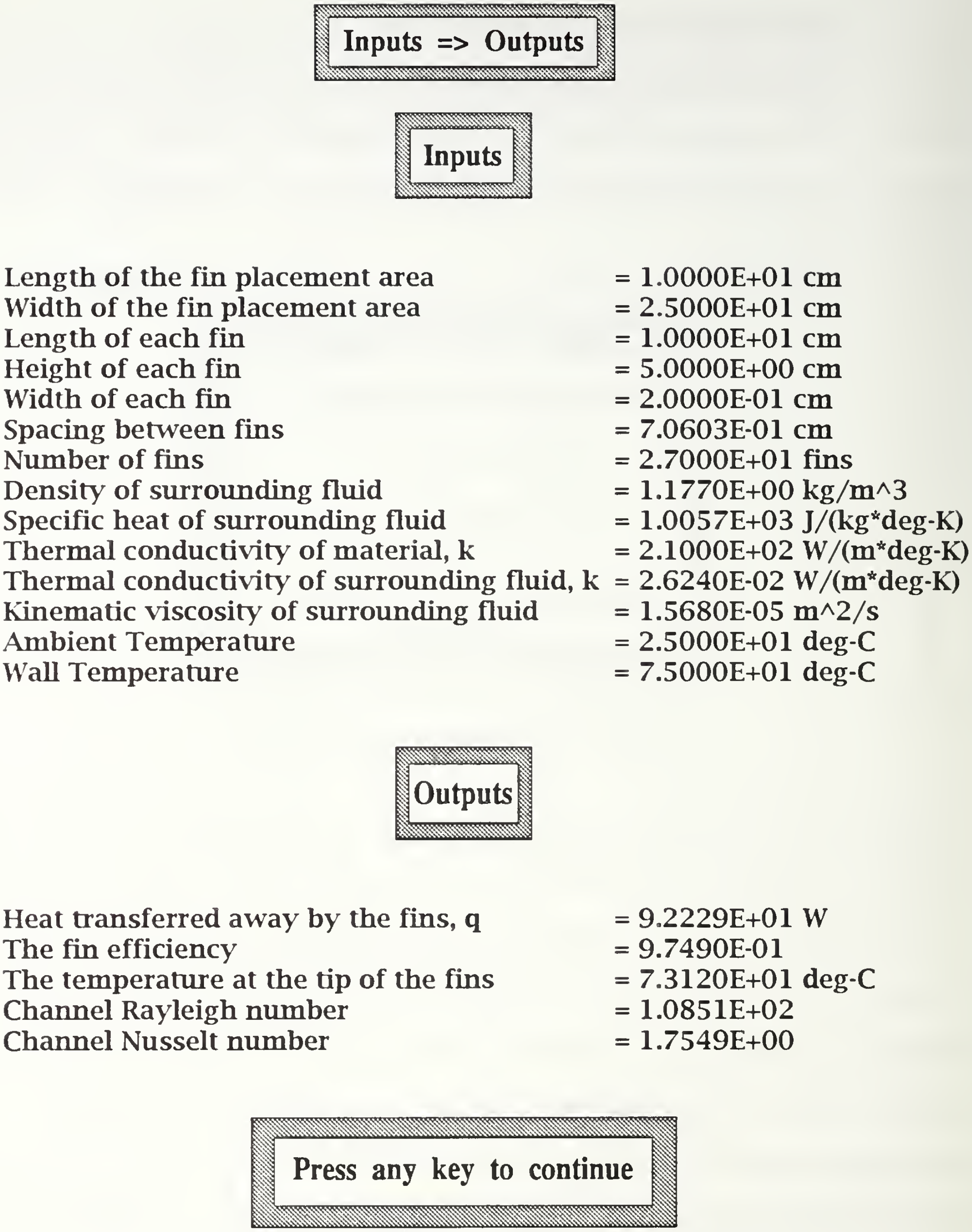
First, the staggered fin problem is examined using the spacing and number of fins found in the previous non-staggered fin example. Pressing any key after viewing the drawing in Figure 6-8 results in the continuation menu in Figure 6-10.



Do you wish to continue ?
1) Exit to DOS
2) Continue
Input your selection: [2]
Press enter to accept default

Figure 6-10. Continuation Menu

Pressing Enter will allow the user to continue in the program. All the defaults are set to the values inputted by the user in the preceding problem to facilitate rapid sensitivity analysis. After proceeding through the screens in Figures 6-2, 6-3, and 6-4, the first item, "No Optimization," is chosen from the menu in Figure 6-5. This option will allow the user to input the fin spacing and number of fins rather than conducting an optimization of those values. The parameters required by the heat transfer equations are inputted in the format demonstrated in Figure 6-6. Once the user has supplied the required inputs, the input-output summary screens in Figure 6-11 are presented.



```
Inputs => Outputs

Inputs

Length of the fin placement area                  = 1.0000E+01 cm
Width of the fin placement area                   = 2.5000E+01 cm
Length of each fin                                = 1.0000E+01 cm
Height of each fin                                = 5.0000E+00 cm
Width of each fin                                 = 2.0000E-01 cm
Spacing between fins                              = 7.0603E-01 cm
Number of fins                                    = 2.7000E+01 fins
Density of surrounding fluid                      = 1.1770E+00 kg/m^3
Specific heat of surrounding fluid                = 1.0057E+03 J/(kg*deg-K)
Thermal conductivity of material, k               = 2.1000E+02 W/(m*deg-K)
Thermal conductivity of surrounding fluid, k      = 2.6240E-02 W/(m*deg-K)
Kinematic viscosity of surrounding fluid          = 1.5680E-05 m^2/s
Ambient Temperature                               = 2.5000E+01 deg-C
Wall Temperature                                  = 7.5000E+01 deg-C

Outputs

Heat transferred away by the fins, q              = 9.2229E+01 W
The fin efficiency                                = 9.7490E-01
The temperature at the tip of the fins            = 7.3120E+01 deg-C
Channel Rayleigh number                           = 1.0851E+02
Channel Nusselt number                            = 1.7549E+00

Press any key to continue
```

Figure 6-11. Input-Output Summary

The value for the single array heat transfer rate, q, is doubled to obtain q_{total} for the given wall area.

$$q_{total} = 2(92.229) = 184.46 \text{ W} \tag{6-1}$$

The improvement is

$$\frac{184.46 - 138.16}{138.16} = 33.5\% \tag{6-2}$$

and one may conclude that staggering the arrays produces a 33.5% increase in the heat transfer rate, without any change in the number of fins, spacing, or materials required. Unfortunately the machining required to produce staggered fin arrays may be expensive.

2. Optimization of Spacing and Number of Fins

The increase in the heat transfer rate shown in Equation 6-2 can be further enhanced by optimizing the number of fins and spacing in the individual fin arrays. Again the third item is chosen from the menu in Figure 6-5. The input-output summary screens produced are shown in Figure 6-12. The value obtained for q is again doubled to obtain q_{total} for the given wall dimensions.

$$q_{total} = 2(92.944) = 185.89 \text{ W} \tag{6-3}$$

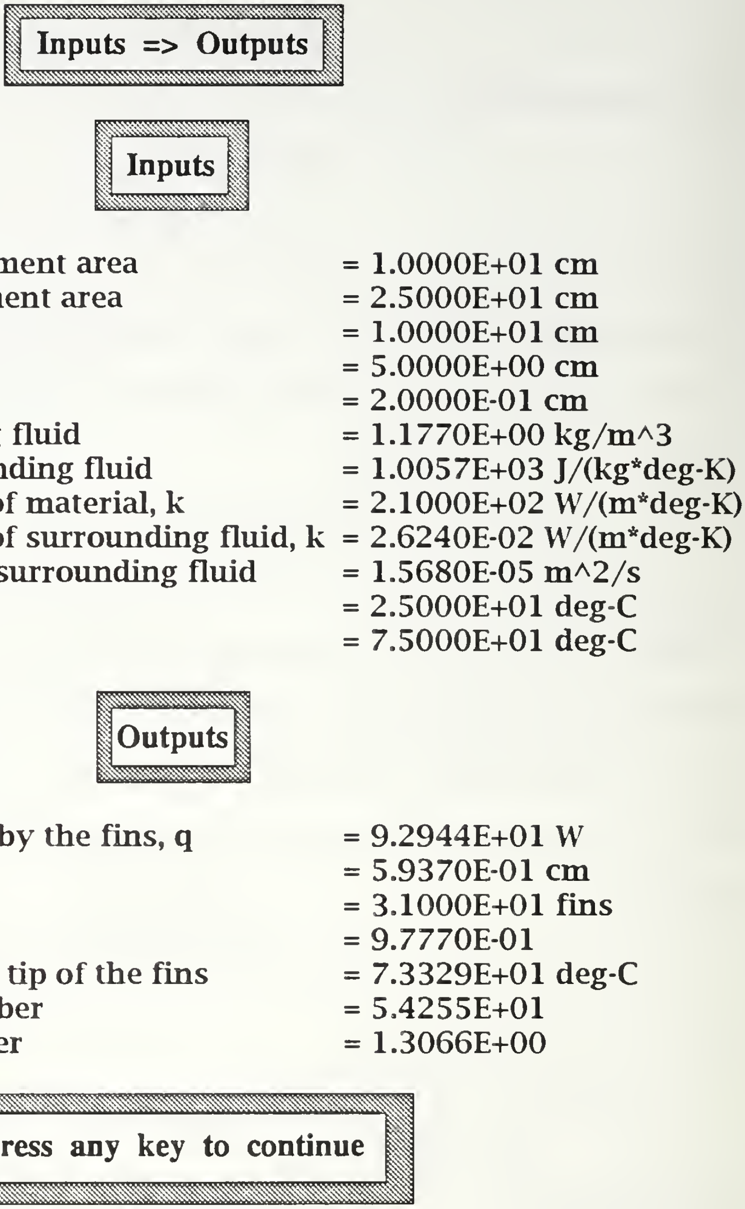
and

$$\frac{185.89 - 138.16}{138.16} = 34.5\% \tag{6-4}$$

and, in addition

$$\frac{185.89 - 184.46}{184.46} = 0.775\% \tag{6-5}$$

The percentage increase found in Equation 6-5 is small, since the non-staggered array of fins had already been previously optimized.



```
Inputs => Outputs

Inputs

Length of the fin placement area                 = 1.0000E+01 cm
Width of the fin placement area                  = 2.5000E+01 cm
Length of each fin                               = 1.0000E+01 cm
Height of each fin                               = 5.0000E+00 cm
Width of each fin                                = 2.0000E-01 cm
Density of surrounding fluid                     = 1.1770E+00 kg/m^3
Specific heat of surrounding fluid               = 1.0057E+03 J/(kg*deg-K)
Thermal conductivity of material, k              = 2.1000E+02 W/(m*deg-K)
Thermal conductivity of surrounding fluid, k     = 2.6240E-02 W/(m*deg-K)
Kinematic viscosity of surrounding fluid         = 1.5680E-05 m^2/s
Ambient Temperature                              = 2.5000E+01 deg-C
Wall Temperature                                 = 7.5000E+01 deg-C

Outputs

Heat transferred away by the fins, q             = 9.2944E+01 W
Spacing between fins                             = 5.9370E-01 cm
Number of fins                                   = 3.1000E+01 fins
The fin efficiency                               = 9.7770E-01
The temperature at the tip of the fins           = 7.3329E+01 deg-C
Channel Rayleigh number                          = 5.4255E+01
Channel Nusselt number                           = 1.3066E+00

Press any key to continue
```

Figure 6-12. Input-Output Summary

VII. CONCLUSION

In the design of electronic equipment, a proper heat sink configuration is essential. As the design example in the previous section demonstrates, the computer program developed for this thesis can serve to greatly simplify and accelerate the fin design process. The program should prove to be valuable tool to electronic component designers, especially those with a limited background in heat transfer and fin optimization theory. A listing of the source code for the computer program is included in the Appendix.

APPENDIX

SOURCE CODE FOR THE COMPUTER PROGRAM

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :             A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    TEXT_IO, COMMON_DISPLAY_TYPES, TTY, CURSOR, VIDEO,
        FINOPT_SINGLE, FINOPT_MULTIPLE, FINOPT_PICTURES,
FINOPT_DRAWINGS;

use     TEXT_IO, COMMON_DISPLAY_TYPES, FINOPT_SINGLE, FINOPT_MULTIPLE;

procedure FINOPT is
   PAUSE, CONTINUE, UNITS, FIN_SING_MULT, FIN_CYL_RECT,
   FIN_OPT_TYP, DEFAULT_KEY                                      :
INTEGER;

   SPACING_ENGLISH, DENSITY_ENGLISH, SPECIFIC_HEAT_ENGLISH,
   NU_ENGLISH, K_FLUID_ENGLISH, WALL_LENGTH_ENGLISH,
   WALL_WIDTH_ENGLISH, DIAMETER_ENGLISH, HEIGHT_ENGLISH,
   WIDTH_ENGLISH, LENGTH_ENGLISH, VOLUME_ENGLISH, H_ENGLISH,
   K_ENGLISH, T_AMBIENT_ENGLISH, T_WALL_ENGLISH, Q_ENGLISH,
   SPACING_SI, DENSITY_SI, SPECIFIC_HEAT_SI, NU_SI,
   K_FLUID_SI, WALL_LENGTH_SI, WALL_WIDTH_SI, DIAMETER_SI,
   HEIGHT_SI, WIDTH_SI, LENGTH_SI, VOLUME_SI, H_SI, K_SI,
   T_AMBIENT_SI, T_WALL_SI, Q_SI, SPACING, DENSITY,
   SPECIFIC_HEAT, NU, K_FLUID, WALL_LENGTH, WALL_WIDTH,
   DIAMETER, HEIGHT, WIDTH, LENGTH, VOLUME, H, K, T_AMBIENT,
   T_WALL, Q, CONVERT_DIST, CONVERT_TEMP, GRAVITY, G_C,
   AREA_PROFILE, NUM_FINS, NUM_FINS_ENGLISH, NUM_FINS_SI   : FLOAT;

   PI : constant := 3.14159_26535_89793_23846_26433_83279_50288_41972;

   SPACING_UNITS, WALL_LENGTH_UNITS,
   WALL_WIDTH_UNITS, DIAMETER_UNITS, HEIGHT_UNITS,
   WIDTH_UNITS, LENGTH_UNITS                              :
STRING(1..2);

   VOLUME_UNITS, NUM_FINS_UNITS                           :
STRING(1..4);

   T_UNITS                                                :
STRING(1..5);

   NU_UNITS, Q_UNITS                                      :
STRING(1..6);
```

```
   DENSITY_UNITS                                               :
STRING(1..8);

   NUMBER_OUT                                                  :
STRING(1..10);

   WIDTH_MSG, LENGTH_MSG, DIAMETER_MSG,
   HEIGHT_MSG, SPACING_MSG, WALL_LENGTH_MSG,
   WALL_WIDTH_MSG                                              :
STRING(1..13);

   SPECIFIC_HEAT_UNITS                                         :
STRING(1..15);

   K_UNITS                                                     :
STRING(1..17);

   H_UNITS                                                     :
STRING(1..19);

   INPUT_MSG                                                   :
STRING(1..33);

   CHAR                                                        : CHARACTER;

   package FLOAT_INOUT is new FLOAT_IO(FLOAT);
   use FLOAT_INOUT;

begin

----------------------------------------------------------------------
--                          Introduction Page                        --
----------------------------------------------------------------------
   VIDEO.SET_COLOR_PALETTE (BLUE);
   FINOPT_PICTURES.THESIS_MSG;

----------------------------------------------------------------------
--                        Output Program Name                        --
----------------------------------------------------------------------
   FINOPT_PICTURES.FINOPT_MSG;

----------------------------------------------------------------------
--                Initialize Variables English System                --
----------------------------------------------------------------------
   SPACING_ENGLISH := 0.5;
-- Spacing (in)
   DENSITY_ENGLISH := 0.05928;
-- Density of surrounding fluid (lbm/ft^3)
   SPECIFIC_HEAT_ENGLISH := 0.2404;
-- Specific heat of surrounding fluid (BTU/(lbm*deg-R))
   NU_ENGLISH := 19.1774E-5;
-- Kinematic viscosity of surrounding fluid (ft^2/s)
   K_FLUID_ENGLISH := 0.01608;
-- Thermal conductivity of surrounding fluid (BTU/(hr*ft*deg-R))
   WALL_LENGTH_ENGLISH := 6.0;
-- Length of multi-fin placement area (in)
```

```
   WALL_WIDTH_ENGLISH := 9.0;
-- Width of multi-fin placement area (in)
   DIAMETER_ENGLISH := 0.3125;
-- Diameter (in)
   HEIGHT_ENGLISH := 4.5;
-- Height (in)
   WIDTH_ENGLISH := 0.0625;
-- Width (in)
   LENGTH_ENGLISH := 2.25;
-- Length (in)
   VOLUME_ENGLISH := 0.3451;
-- Volume (in^3)
   H_ENGLISH := 1.0;
-- Convection heat transfer coefficient (BTU/(hr*ft^2*deg-R))
   K_ENGLISH := 24.8;
-- Thermal conductivity (BTU/(hr*ft*deg-R))
   T_AMBIENT_ENGLISH := 70.0;
-- Ambient Temperature (deg-F)
   T_WALL_ENGLISH := 200.0;
-- Wall temperature (deg-F)
   Q_ENGLISH := 3.13;
-- Heat transferred (BTU/hr)

------------------------------------------------------------------------
--                  Initialize Variables SI System                    --
------------------------------------------------------------------------
   SPACING_SI := 1.04;
-- Spacing (cm)
   DENSITY_SI := 1.177;
-- Density of surrounding fluid (kg/m^3)
   SPECIFIC_HEAT_SI := 1005.7;
-- Specific heat of surrounding fluid (J/(kg*deg-K))
   NU_SI := 1.568E-5;
-- Kinematic viscosity of surrounding fluid (m^2/s)
   K_FLUID_SI := 0.02624;
-- Thermal conductivity of surrounding fluid (W/(m*deg-K))
   WALL_LENGTH_SI := 9.0;
-- Length of multi-fin placement area (in)
   WALL_WIDTH_SI := 22.14;
-- Width of multi-fin placement area (in)
   DIAMETER_SI := 0.7;
-- Diameter (cm)
   HEIGHT_SI := 4.7;
-- Height (cm)
   WIDTH_SI := 0.18;
-- Width (cm)
   LENGTH_SI := 9.0;
-- Length (cm)
   VOLUME_SI := 16.3516;
-- Volume (cm^3)
   H_SI := 7.0;
-- Convection heat transfer coefficient (W/(m^2*deg-K))
   K_SI := 236.0;
-- Thermal conductivity (W/(m*deg-K))
   T_AMBIENT_SI := 20.0;
-- Ambient temperature (deg-C)
```

```
   T_WALL_SI := 60.0;
-- Wall temperature (deg-C)
   Q_SI := 5.902;
-- Heat transferred (W)

------------------------------------------------------------------------
--                                Continue?                           --
------------------------------------------------------------------------
   loop
      TTY.CLEAR_SCREEN;
      TTY.PUT ( 6, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 7, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
      TTY.PUT (10, 21, "   ", YELLOW, CYAN);
      TTY.PUT (10, 55, "   ", YELLOW, CYAN);
      TTY.PUT (11, 21, "   ", YELLOW, CYAN);
      TTY.PUT (11, 55, "   ", YELLOW, CYAN);
      TTY.PUT (12, 21, "   ", YELLOW, CYAN);
      TTY.PUT (12, 55, "   ", YELLOW, CYAN);
      TTY.PUT (13, 21, "   ", YELLOW, CYAN);
      TTY.PUT (13, 55, "   ", YELLOW, CYAN);
      TTY.PUT (14, 21, "   ", YELLOW, CYAN);
      TTY.PUT (14, 55, "   ", YELLOW, CYAN);
      TTY.PUT (15, 21, "   ", YELLOW, CYAN);
      TTY.PUT (15, 55, "   ", YELLOW, CYAN);
      TTY.PUT (16, 21, "   ", YELLOW, CYAN);
      TTY.PUT (16, 55, "   ", YELLOW, CYAN);
      TTY.PUT (17, 21, "   ", YELLOW, CYAN);
      TTY.PUT (17, 55, "   ", YELLOW, CYAN);
      TTY.PUT (18, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT (19, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 24, "                               ", YELLOW, RED);
      TTY.PUT ( 9, 24, "   Do you wish to continue ?   ", BRIGHT_WHITE,
      RED);
      TTY.PUT (10, 24, "                               ", YELLOW, RED);
      TTY.PUT (11, 24, "         1) Exit to DOS        ", YELLOW, RED);
      TTY.PUT (12, 24, "                               ", YELLOW, RED);
      TTY.PUT (13, 24, "         2) Continue           ", YELLOW, RED);
      TTY.PUT (14, 24, "                               ", YELLOW, RED);
      TTY.PUT (15, 24, "   Input your selection: [2]   ", YELLOW, RED);
      TTY.PUT (16, 24, " Press enter to accept default ", BRIGHT_WHITE,
RED);
      TTY.PUT (17, 24, "                               ", YELLOW, RED);
      CURSOR.SET_SIZE(13,13);
      loop
         CURSOR.MOVE (15, 50);
         TTY.GET (CONTINUE, CHAR);
         if CONTINUE = 2 or CONTINUE = 3 or CONTINUE = 28  then
            exit;
         else
            TTY.PUT (21, 24, " Improper input, please reenter ",
            BLUE, CYAN);
         end if;
      end loop;
      CURSOR.INHIBIT;

------------------------------------------------------------------------
--                        Do Not Continue                             --
------------------------------------------------------------------------
      exit when CONTINUE = 2;

------------------------------------------------------------------------
--                     Continue With Program                          --
------------------------------------------------------------------------

------------------------------------------------------------------------
--                       Select Unit System                           --
------------------------------------------------------------------------
      TTY.CLEAR_SCREEN;
      TTY.PUT ( 6, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 7, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
      TTY.PUT (10, 21, "   ", YELLOW, CYAN);
      TTY.PUT (10, 55, "   ", YELLOW, CYAN);
      TTY.PUT (11, 21, "   ", YELLOW, CYAN);
      TTY.PUT (11, 55, "   ", YELLOW, CYAN);
      TTY.PUT (12, 21, "   ", YELLOW, CYAN);
      TTY.PUT (12, 55, "   ", YELLOW, CYAN);
      TTY.PUT (13, 21, "   ", YELLOW, CYAN);
      TTY.PUT (13, 55, "   ", YELLOW, CYAN);
      TTY.PUT (14, 21, "   ", YELLOW, CYAN);
      TTY.PUT (14, 55, "   ", YELLOW, CYAN);
      TTY.PUT (15, 21, "   ", YELLOW, CYAN);
      TTY.PUT (15, 55, "   ", YELLOW, CYAN);
      TTY.PUT (16, 21, "   ", YELLOW, CYAN);
      TTY.PUT (16, 55, "   ", YELLOW, CYAN);
      TTY.PUT (17, 21, "   ", YELLOW, CYAN);
      TTY.PUT (17, 55, "   ", YELLOW, CYAN);
      TTY.PUT (18, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT (19, 21, "                                     ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 24, "                               ", YELLOW, RED);
      TTY.PUT ( 9, 24, "   Select Desired Unit System  ",
      BRIGHT_WHITE, RED);
      TTY.PUT (10, 24, "                               ", YELLOW, RED);
      TTY.PUT (11, 24, "     1) English Engineering    ", YELLOW, RED);
      TTY.PUT (12, 24, "                               ", YELLOW, RED);
      TTY.PUT (13, 24, "     2) SI                     ", YELLOW, RED);
      TTY.PUT (14, 24, "                               ", YELLOW, RED);
      TTY.PUT (15, 24, "   Input your selection: [2]  ", YELLOW, RED);
      TTY.PUT (16, 24, " Press enter to accept default ", BRIGHT_WHITE,
RED);
      TTY.PUT (17, 24, "                              ", YELLOW, RED);
      CURSOR.SET_SIZE(13,13);
      loop
         CURSOR.MOVE (15, 50);
         TTY.GET (UNITS, CHAR);
         if UNITS = 2 or UNITS = 3 or UNITS = 28  then
            exit;
         else
            TTY.PUT (21, 24, " Improper input, please reenter ",
            BLUE, CYAN);
         end if;
      end loop;
      CURSOR.INHIBIT;

----------------------------------------------------------------------
--                  Use English Engineering System                  --
----------------------------------------------------------------------
      if (UNITS = 2) then
         CONVERT_DIST := 12.0;
--       Convert inches to feet
         CONVERT_TEMP := 460.0;
--       Convert deg-F to deg-R
         GRAVITY := 32.2;
--       Acceleration of gravity (ft/s^2)
         G_C := 32.2;
--       Conversion factor (lbm*ft/(lbf*s^2))
         SPACING := SPACING_ENGLISH;
         SPACING_UNITS := "in";
         DENSITY := DENSITY_ENGLISH;
         DENSITY_UNITS := "lbm/ft^3";
         SPECIFIC_HEAT := SPECIFIC_HEAT_ENGLISH;
         SPECIFIC_HEAT_UNITS := "BTU/(lbm*deg-R)";
         NU := NU_ENGLISH;
         NU_UNITS := "ft^2/s";
         WALL_LENGTH := WALL_LENGTH_ENGLISH;
         WALL_LENGTH_UNITS := "in";
         WALL_WIDTH := WALL_WIDTH_ENGLISH;
         WALL_WIDTH_UNITS := "in";
         NUM_FINS_UNITS := "fins";
         DIAMETER := DIAMETER_ENGLISH;
         DIAMETER_UNITS := "in";
         HEIGHT := HEIGHT_ENGLISH;
         HEIGHT_UNITS := "in";
         WIDTH := WIDTH_ENGLISH;
         WIDTH_UNITS := "in";
         LENGTH := LENGTH_ENGLISH;
         LENGTH_UNITS := "in";
         VOLUME := VOLUME_ENGLISH;
         VOLUME_UNITS := "in^3";
         H := H_ENGLISH;
         H_UNITS := "BTU/(hr*ft^2*deg-R)";
         K := K_ENGLISH;
         K_FLUID := K_FLUID_ENGLISH;
         K_UNITS := "BTU/(hr*ft*deg-R)";
         T_AMBIENT := T_AMBIENT_ENGLISH;
         T_WALL := T_WALL_ENGLISH;
         T_UNITS := "deg-F";
         Q := Q_ENGLISH;
         Q_UNITS := "BTU/hr";

------------------------------------------------------------------------
--                         Use SI System                              --
------------------------------------------------------------------------
      else
         CONVERT_DIST := 100.0;
--       Convert centimeters to meters
         CONVERT_TEMP := 273.15;
--       Convert deg-C to deg-K
         GRAVITY := 9.81;
--       Acceleration of gravity (m/s^2)
         G_C := 1.0;
--       Conversion factor (kg*m/(N*s^2))
         SPACING := SPACING_SI;
         SPACING_UNITS := "cm";
         DENSITY := DENSITY_SI;
         DENSITY_UNITS := "kg/m^3  ";
         SPECIFIC_HEAT := SPECIFIC_HEAT_SI;
         SPECIFIC_HEAT_UNITS := "J/(kg*deg-K)    ";
         NU := NU_SI;
         NU_UNITS := "m^2/s ";
         WALL_LENGTH := WALL_LENGTH_SI;
         WALL_LENGTH_UNITS := "cm";
         WALL_WIDTH := WALL_WIDTH_SI;
         WALL_WIDTH_UNITS := "cm";
         NUM_FINS_UNITS := "fins";
         DIAMETER := DIAMETER_SI;
         DIAMETER_UNITS := "cm";
         HEIGHT := HEIGHT_SI;
         HEIGHT_UNITS := "cm";
         WIDTH := WIDTH_SI;
         WIDTH_UNITS := "cm";
         LENGTH := LENGTH_SI;
         LENGTH_UNITS := "cm";
         VOLUME := VOLUME_SI;
         VOLUME_UNITS := "cm^3";
         H := H_SI;
         H_UNITS := "W/(m^2*deg-K)       ";
         K := K_SI;
         K_FLUID := K_FLUID_SI;
         K_UNITS := "W/(m*deg-K)       ";
         T_AMBIENT := T_AMBIENT_SI;
         T_WALL := T_WALL_SI;
         T_UNITS := "deg-C";
         Q := Q_SI;
         Q_UNITS := "W      ";
      end if;

------------------------------------------------------------------------
--             Select Single or Multiple Fin Optimization             --
```

```
------------------------------------------------------------------------
      TTY.CLEAR_SCREEN;
      TTY.PUT ( 6, 21, "                                      ",
      YELLOW, CYAN);
      TTY.PUT ( 7, 21, "                                      ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
      TTY.PUT (10, 21, "   ", YELLOW, CYAN);
      TTY.PUT (10, 55, "   ", YELLOW, CYAN);
      TTY.PUT (11, 21, "   ", YELLOW, CYAN);
      TTY.PUT (11, 55, "   ", YELLOW, CYAN);
      TTY.PUT (12, 21, "   ", YELLOW, CYAN);
      TTY.PUT (12, 55, "   ", YELLOW, CYAN);
      TTY.PUT (13, 21, "   ", YELLOW, CYAN);
      TTY.PUT (13, 55, "   ", YELLOW, CYAN);
      TTY.PUT (14, 21, "   ", YELLOW, CYAN);
      TTY.PUT (14, 55, "   ", YELLOW, CYAN);
      TTY.PUT (15, 21, "   ", YELLOW, CYAN);
      TTY.PUT (15, 55, "   ", YELLOW, CYAN);
      TTY.PUT (16, 21, "   ", YELLOW, CYAN);
      TTY.PUT (16, 55, "   ", YELLOW, CYAN);
      TTY.PUT (17, 21, "   ", YELLOW, CYAN);
      TTY.PUT (17, 55, "   ", YELLOW, CYAN);
      TTY.PUT (18, 21, "                                      ",
      YELLOW, CYAN);
      TTY.PUT (19, 21, "                                      ",
      YELLOW, CYAN);
      TTY.PUT ( 8, 24, "                               ", YELLOW, RED);
      TTY.PUT ( 9, 24, "    Select Fin Optimization    ",
      BRIGHT_WHITE, RED);
      TTY.PUT (10, 24, "                               ", YELLOW, RED);
      TTY.PUT (11, 24, "      1) Single Fin            ", YELLOW, RED);
      TTY.PUT (12, 24, "                               ", YELLOW, RED);
      TTY.PUT (13, 24, "      2) Multiple Fins         ", YELLOW, RED);
      TTY.PUT (14, 24, "                               ", YELLOW, RED);
      TTY.PUT (15, 24, "   Input your selection: [2]   ", YELLOW, RED);
      TTY.PUT (16, 24, " Press enter to accept default ", BRIGHT_WHITE,
RED);
      TTY.PUT (17, 24, "                               ", YELLOW, RED);
      CURSOR.SET_SIZE(13,13);
      loop
         CURSOR.MOVE (15, 50);
         TTY.GET (FIN_SING_MULT, CHAR);
         if FIN_SING_MULT = 2 or FIN_SING_MULT = 3 or
         FIN_SING_MULT = 28  then
            exit;
         else
            TTY.PUT (21, 24, " Improper input, please reenter ",
            BLUE, CYAN);
         end if;
      end loop;
      CURSOR.INHIBIT;
```

```
------------------------------------------------------------------------
--   Single Fin Problem, Select Cylindrical or Rectangular Fin Type   --
------------------------------------------------------------------------
      if (FIN_SING_MULT = 2) then
         TTY.CLEAR_SCREEN;
         TTY.PUT ( 6, 21, "                                    ",
         YELLOW, CYAN);
         TTY.PUT ( 7, 21, "                                    ",
         YELLOW, CYAN);
         TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
         TTY.PUT (10, 21, "   ", YELLOW, CYAN);
         TTY.PUT (10, 55, "   ", YELLOW, CYAN);
         TTY.PUT (11, 21, "   ", YELLOW, CYAN);
         TTY.PUT (11, 55, "   ", YELLOW, CYAN);
         TTY.PUT (12, 21, "   ", YELLOW, CYAN);
         TTY.PUT (12, 55, "   ", YELLOW, CYAN);
         TTY.PUT (13, 21, "   ", YELLOW, CYAN);
         TTY.PUT (13, 55, "   ", YELLOW, CYAN);
         TTY.PUT (14, 21, "   ", YELLOW, CYAN);
         TTY.PUT (14, 55, "   ", YELLOW, CYAN);
         TTY.PUT (15, 21, "   ", YELLOW, CYAN);
         TTY.PUT (15, 55, "   ", YELLOW, CYAN);
         TTY.PUT (16, 21, "   ", YELLOW, CYAN);
         TTY.PUT (16, 55, "   ", YELLOW, CYAN);
         TTY.PUT (17, 21, "   ", YELLOW, CYAN);
         TTY.PUT (17, 55, "   ", YELLOW, CYAN);
         TTY.PUT (18, 21, "                                    ",
         YELLOW, CYAN);
         TTY.PUT (19, 21, "                                    ",
         YELLOW, CYAN);
         TTY.PUT ( 8, 24, "                               ", YELLOW,
RED);
         TTY.PUT ( 9, 24, "    Select Desired Fin Shape   ",
         BRIGHT_WHITE, RED);
         TTY.PUT (10, 24, "                               ", YELLOW,
RED);
         TTY.PUT (11, 24, "      1) Cylindrical Spine     ", YELLOW,
RED);
         TTY.PUT (12, 24, "                               ", YELLOW,
RED);
         TTY.PUT (13, 24, "      2) Rectangular fin       ", YELLOW,
RED);
         TTY.PUT (14, 24, "                               ", YELLOW,
RED);
         TTY.PUT (15, 24, "   Input your selection: [2]   ", YELLOW,
RED);
         TTY.PUT (16, 24, " Press enter to accept default ",
         BRIGHT_WHITE, RED);
         TTY.PUT (17, 24, "                               ", YELLOW,
RED);
         CURSOR.SET_SIZE(13,13);
         loop
            CURSOR.MOVE (15, 50);
            TTY.GET (FIN_CYL_RECT, CHAR);
            if FIN_CYL_RECT = 2 or FIN_CYL_RECT = 3 or
            FIN_CYL_RECT = 28  then
               exit;
            else
               TTY.PUT (21, 24, " Improper input, please reenter ",
               BLUE, CYAN);
            end if;
         end loop;
         CURSOR.INHIBIT;

------------------------------------------------------------------------
--                   Single Fin Problem, Cylindrical Spine,           --
--                         Draw Cylindrical Spine                     --
------------------------------------------------------------------------
         if (FIN_CYL_RECT = 2) then
            DIAMETER_MSG := "Diameter     ";
            HEIGHT_MSG   := "   Height    ";
            FINOPT_DRAWINGS.CYLINDRICAL_DRAWING(DIAMETER_MSG,
HEIGHT_MSG);

------------------------------------------------------------------------
--              Single Fin Problem, Cylindrical Spine                 --
--                      Choose Optimization                           --
------------------------------------------------------------------------
            TTY.CLEAR_SCREEN;
            TTY.PUT ( 2, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 3, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 4, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 4, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 5, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 5, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 6, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 6, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 7, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 7, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
            TTY.PUT (10, 21, "   ", YELLOW, CYAN);
            TTY.PUT (10, 55, "   ", YELLOW, CYAN);
            TTY.PUT (11, 21, "   ", YELLOW, CYAN);
            TTY.PUT (11, 55, "   ", YELLOW, CYAN);
            TTY.PUT (12, 21, "   ", YELLOW, CYAN);
            TTY.PUT (12, 55, "   ", YELLOW, CYAN);
            TTY.PUT (13, 21, "   ", YELLOW, CYAN);
            TTY.PUT (13, 55, "   ", YELLOW, CYAN);
            TTY.PUT (14, 21, "   ", YELLOW, CYAN);
            TTY.PUT (14, 55, "   ", YELLOW, CYAN);
            TTY.PUT (15, 21, "   ", YELLOW, CYAN);
            TTY.PUT (15, 55, "   ", YELLOW, CYAN);
            TTY.PUT (16, 21, "   ", YELLOW, CYAN);
            TTY.PUT (16, 55, "   ", YELLOW, CYAN);
            TTY.PUT (17, 21, "   ", YELLOW, CYAN);
            TTY.PUT (17, 55, "   ", YELLOW, CYAN);
            TTY.PUT (18, 21, "   ", YELLOW, CYAN);
            TTY.PUT (18, 55, "   ", YELLOW, CYAN);
            TTY.PUT (19, 21, "   ", YELLOW, CYAN);
            TTY.PUT (19, 55, "   ", YELLOW, CYAN);
            TTY.PUT (20, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT (21, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 4, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 5, 24, "  Choose Type of Optimization  ",
            BRIGHT_WHITE, RED);
            TTY.PUT ( 6, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 7, 24, "    1) No Optimization         ", YELLOW,
RED);
            TTY.PUT ( 8, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 9, 24, "    2) Maximum heat transfer   ", YELLOW,
RED);
            TTY.PUT (10, 24, "       capability for a given  ", YELLOW,
RED);
            TTY.PUT (11, 24, "       volume                  ", YELLOW,
RED);
            TTY.PUT (12, 24, "                               ", YELLOW,
RED);
            TTY.PUT (13, 24, "    3) Minimum volume for a    ", YELLOW,
RED);
            TTY.PUT (14, 24, "       given heat transfer     ", YELLOW,
RED);
            TTY.PUT (15, 24, "       capability              ", YELLOW,
RED);
            TTY.PUT (16, 24, "                               ", YELLOW,
RED);
            TTY.PUT (17, 24, "   Input your selection: [3]   ", YELLOW,
RED);
            TTY.PUT (18, 24, " Press enter to accept default ",
            BRIGHT_WHITE, RED);
            TTY.PUT (19, 24, "                               ", YELLOW,
RED);
            CURSOR.SET_SIZE(13,13);
            loop
               CURSOR.MOVE (17, 50);
               TTY.GET (FIN_OPT_TYP, CHAR);
               if FIN_OPT_TYP = 2 or FIN_OPT_TYP = 3 or
               FIN_OPT_TYP = 4 or FIN_OPT_TYP = 28  then
                  exit;
               else
                  TTY.PUT (23, 24, " Improper input, please reenter ",
                  BLUE, CYAN);
               end if;
            end loop;
            CURSOR.INHIBIT;
```

```
------------------------------------------------------------------------
--      Single Fin Problem, Cylindrical Spine, No Optimization        --
------------------------------------------------------------------------
            if (FIN_OPT_TYP = 2) then
               CYLINDRICAL_NO_OPT(UNITS, CONVERT_DIST, DIAMETER,
               DIAMETER_UNITS, HEIGHT, HEIGHT_UNITS, H, H_UNITS, K,
               K_UNITS, T_AMBIENT, T_WALL, T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Single Fin Problem, Cylindrical Spine, Maximum Heat           --
--            Transfer Capability for a Given Volume                  --
------------------------------------------------------------------------
            elsif (FIN_OPT_TYP = 3) then
               CYLINDRICAL_GIVEN_VOL(UNITS, CONVERT_DIST, VOLUME,
               VOLUME_UNITS, DIAMETER, DIAMETER_UNITS, HEIGHT,
               HEIGHT_UNITS, H, H_UNITS, K, K_UNITS, T_AMBIENT,
               T_WALL, T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Single Fin Problem, Cylindrical Spine, Minimum Volume         --
--              for a Given Heat Transfer Capability                  --
------------------------------------------------------------------------
            else
               CYLINDRICAL_GIVEN_Q(UNITS, CONVERT_DIST, DIAMETER,
               DIAMETER_UNITS, HEIGHT, HEIGHT_UNITS, H, H_UNITS, K,
               K_UNITS, T_AMBIENT, T_WALL, T_UNITS, Q, Q_UNITS);
            end if;

------------------------------------------------------------------------
--                   Single Fin Problem, Cylindrical Spine            --
--             Draw Cylindrical Spine With Calculated Dimensions      --
------------------------------------------------------------------------
            PUT (DIAMETER_MSG(1..10), DIAMETER, 4, 3);
            DIAMETER_MSG(11) := ' ';
            DIAMETER_MSG(12..13) := DIAMETER_UNITS;
            PUT (HEIGHT_MSG(1..10), HEIGHT, 4, 3);
            HEIGHT_MSG(11) := ' ';
            HEIGHT_MSG(12..13) := HEIGHT_UNITS;
            FINOPT_DRAWINGS.CYLINDRICAL_DRAWING(DIAMETER_MSG,
HEIGHT_MSG);

------------------------------------------------------------------------
--                   Single Fin Problem, Rectangular Fin,             --
--                         Draw Rectangular Fin                       --
------------------------------------------------------------------------
         else
            WIDTH_MSG   := "Width        ";
            LENGTH_MSG  := "Length       ";
            HEIGHT_MSG  := "   Height    ";
            FINOPT_DRAWINGS.RECTANGULAR_DRAWING(WIDTH_MSG, LENGTH_MSG,
            HEIGHT_MSG);

------------------------------------------------------------------------
--                   Single Fin Problem, Rectangular Fin              --
--                      Choose Optimization                           --
------------------------------------------------------------------------
```

```
            TTY.CLEAR_SCREEN;
            TTY.PUT ( 2, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 3, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 4, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 4, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 5, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 5, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 6, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 6, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 7, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 7, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
            TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
            TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
            TTY.PUT (10, 21, "   ", YELLOW, CYAN);
            TTY.PUT (10, 55, "   ", YELLOW, CYAN);
            TTY.PUT (11, 21, "   ", YELLOW, CYAN);
            TTY.PUT (11, 55, "   ", YELLOW, CYAN);
            TTY.PUT (12, 21, "   ", YELLOW, CYAN);
            TTY.PUT (12, 55, "   ", YELLOW, CYAN);
            TTY.PUT (13, 21, "   ", YELLOW, CYAN);
            TTY.PUT (13, 55, "   ", YELLOW, CYAN);
            TTY.PUT (14, 21, "   ", YELLOW, CYAN);
            TTY.PUT (14, 55, "   ", YELLOW, CYAN);
            TTY.PUT (15, 21, "   ", YELLOW, CYAN);
            TTY.PUT (15, 55, "   ", YELLOW, CYAN);
            TTY.PUT (16, 21, "   ", YELLOW, CYAN);
            TTY.PUT (16, 55, "   ", YELLOW, CYAN);
            TTY.PUT (17, 21, "   ", YELLOW, CYAN);
            TTY.PUT (17, 55, "   ", YELLOW, CYAN);
            TTY.PUT (18, 21, "   ", YELLOW, CYAN);
            TTY.PUT (18, 55, "   ", YELLOW, CYAN);
            TTY.PUT (19, 21, "   ", YELLOW, CYAN);
            TTY.PUT (19, 55, "   ", YELLOW, CYAN);
            TTY.PUT (20, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT (21, 21, "                                     ",
            YELLOW, CYAN);
            TTY.PUT ( 4, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 5, 24, "  Choose Type of Optimization  ",
            BRIGHT_WHITE, RED);
            TTY.PUT ( 6, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 7, 24, "    1) No Optimization         ", YELLOW,
RED);
            TTY.PUT ( 8, 24, "                               ", YELLOW,
RED);
            TTY.PUT ( 9, 24, "    2) Maximum heat transfer   ", YELLOW,
RED);
            TTY.PUT (10, 24, "       capability for a given  ", YELLOW,
RED);
```

```
            TTY.PUT (11, 24, "       volume and length       ", YELLOW,
RED);
            TTY.PUT (12, 24, "                               ", YELLOW,
RED);
            TTY.PUT (13, 24, "    3) Minimum volume for a    ", YELLOW,
RED);
            TTY.PUT (14, 24, "       given heat transfer     ", YELLOW,
RED);
            TTY.PUT (15, 24, "       capability              ", YELLOW,
RED);
            TTY.PUT (16, 24, "                               ", YELLOW,
RED);
            TTY.PUT (17, 24, "   Input your selection: [3]   ", YELLOW,
RED);
            TTY.PUT (18, 24, " Press enter to accept default ",
            BRIGHT_WHITE, RED);
            TTY.PUT (19, 24, "                               ", YELLOW,
RED);
            CURSOR.SET_SIZE(13,13);
            loop
               CURSOR.MOVE (17, 50);
               TTY.GET (FIN_OPT_TYP, CHAR);
               if FIN_OPT_TYP = 2 or FIN_OPT_TYP = 3 or
               FIN_OPT_TYP = 4 or FIN_OPT_TYP = 28  then
                  exit;
               else
                  TTY.PUT (23, 24, " Improper input, please reenter ",
                  BLUE, CYAN);
               end if;
            end loop;
            CURSOR.INHIBIT;

------------------------------------------------------------------------
--      Single Fin Problem, Rectangular Fin, No Optimization          --
------------------------------------------------------------------------
            if (FIN_OPT_TYP = 2) then
               RECTANGULAR_NO_OPT(UNITS, CONVERT_DIST, LENGTH,
               LENGTH_UNITS, HEIGHT, HEIGHT_UNITS, WIDTH,
               WIDTH_UNITS, H, H_UNITS, K, K_UNITS, T_AMBIENT,
               T_WALL, T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Single Fin Problem, Rectangular Fin, Maximum Heat             --
--      Transfer Capability for a Given Volume and Length              -
-
------------------------------------------------------------------------
            elsif (FIN_OPT_TYP = 3) then
               RECTANGULAR_GIVEN_VOL(UNITS, CONVERT_DIST, VOLUME,
               VOLUME_UNITS, LENGTH, LENGTH_UNITS, HEIGHT, HEIGHT_UNITS,
               WIDTH, WIDTH_UNITS, H, H_UNITS, K, K_UNITS,
               T_AMBIENT, T_WALL, T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Single Fin Problem, Rectangular Fin, Minimum Volume           --
--              for a Given Heat Transfer Capability                  --
------------------------------------------------------------------------
```

```
            else
               RECTANGULAR_GIVEN_Q(UNITS, CONVERT_DIST, LENGTH,
               LENGTH_UNITS, HEIGHT, HEIGHT_UNITS, WIDTH,
               WIDTH_UNITS, H, H_UNITS, K, K_UNITS, T_AMBIENT,
               T_WALL, T_UNITS, Q, Q_UNITS);
            end if;

-------------------------------------------------------------------------
--                   Single Fin Problem, Rectangular Fin,              --
--             Draw Rectangular Fin With Calculated Dimensions         --
-------------------------------------------------------------------------
            PUT (WIDTH_MSG(1..10), WIDTH, 4, 3);
            WIDTH_MSG(11) := ' ';
            WIDTH_MSG(12..13) := WIDTH_UNITS;
            PUT (LENGTH_MSG(1..10), LENGTH, 4, 3);
            LENGTH_MSG(11) := ' ';
            LENGTH_MSG(12..13) := LENGTH_UNITS;
            PUT (HEIGHT_MSG(1..10), HEIGHT, 4, 3);
            HEIGHT_MSG(11) := ' ';
            HEIGHT_MSG(12..13) := HEIGHT_UNITS;
            FINOPT_DRAWINGS.RECTANGULAR_DRAWING(WIDTH_MSG, LENGTH_MSG,
            HEIGHT_MSG);
         end if;

-------------------------------------------------------------------------
--    Multiple Fin Problem, Rectangular Fins, Draw Rectangular Fins    --
-------------------------------------------------------------------------
      else
         WIDTH_MSG       := "     Width   ";
         LENGTH_MSG      := "Length       ";
         HEIGHT_MSG      := "       Height";
         SPACING_MSG     := "   Spacing   ";
         WALL_LENGTH_MSG := " Wall Length ";
         WALL_WIDTH_MSG  := " Wall Width  ";
         FINOPT_DRAWINGS.MULTI_FIN_DRAWING(WIDTH_MSG, LENGTH_MSG,
         HEIGHT_MSG, SPACING_MSG, WALL_LENGTH_MSG, WALL_WIDTH_MSG);

-------------------------------------------------------------------------
--    Multiple Fin Problem, Rectangular Fins, Choose Optimization      --
-------------------------------------------------------------------------
         TTY.CLEAR_SCREEN;
         TTY.PUT ( 2, 21, "                                     ",
         YELLOW, CYAN);
         TTY.PUT ( 3, 21, "                                     ",
         YELLOW, CYAN);
         TTY.PUT ( 4, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 4, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 5, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 5, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 6, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 6, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 7, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 7, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 8, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 8, 55, "   ", YELLOW, CYAN);
         TTY.PUT ( 9, 21, "   ", YELLOW, CYAN);
         TTY.PUT ( 9, 55, "   ", YELLOW, CYAN);
         TTY.PUT (10, 21, "   ", YELLOW, CYAN);
         TTY.PUT (10, 55, "   ", YELLOW, CYAN);
         TTY.PUT (11, 21, "   ", YELLOW, CYAN);
         TTY.PUT (11, 55, "   ", YELLOW, CYAN);
         TTY.PUT (12, 21, "   ", YELLOW, CYAN);
         TTY.PUT (12, 55, "   ", YELLOW, CYAN);
         TTY.PUT (13, 21, "   ", YELLOW, CYAN);
         TTY.PUT (13, 55, "   ", YELLOW, CYAN);
         TTY.PUT (14, 21, "   ", YELLOW, CYAN);
         TTY.PUT (14, 55, "   ", YELLOW, CYAN);
         TTY.PUT (15, 21, "   ", YELLOW, CYAN);
         TTY.PUT (15, 55, "   ", YELLOW, CYAN);
         TTY.PUT (16, 21, "   ", YELLOW, CYAN);
         TTY.PUT (16, 55, "   ", YELLOW, CYAN);
         TTY.PUT (17, 21, "   ", YELLOW, CYAN);
         TTY.PUT (17, 55, "   ", YELLOW, CYAN);
         TTY.PUT (18, 21, "   ", YELLOW, CYAN);
         TTY.PUT (18, 55, "   ", YELLOW, CYAN);
         TTY.PUT (19, 21, "   ", YELLOW, CYAN);
         TTY.PUT (19, 55, "   ", YELLOW, CYAN);
         TTY.PUT (20, 21, "                                     ",
         YELLOW, CYAN);
         TTY.PUT (21, 21, "                                     ",
         YELLOW, CYAN);
         TTY.PUT ( 4, 24, "                               ", YELLOW,
RED);
         TTY.PUT ( 5, 24, "  Choose Type of Optimization  ",
         BRIGHT_WHITE, RED);
         TTY.PUT ( 6, 24, "                               ", YELLOW,
RED);
         TTY.PUT ( 7, 24, "    1) No Optimization         ", YELLOW,
RED);
         TTY.PUT ( 8, 24, "                               ", YELLOW,
RED);
         TTY.PUT ( 9, 24, "    2) Maximum heat transfer   ", YELLOW,
RED);
         TTY.PUT (10, 24, "       capability from each    ", YELLOW,
RED);
         TTY.PUT (11, 24, "       fin in a given area     ", YELLOW,
RED);
         TTY.PUT (12, 24, "                               ", YELLOW,
RED);
         TTY.PUT (13, 24, "    3) Maximum heat transfer   ", YELLOW,
RED);
         TTY.PUT (14, 24, "       capability for a given  ", YELLOW,
RED);
         TTY.PUT (15, 24, "       area                    ", YELLOW,
RED);
         TTY.PUT (16, 24, "                               ", YELLOW,
RED);
         TTY.PUT (17, 24, "   Input your selection: [3]   ", YELLOW,
RED);
         TTY.PUT (18, 24, " Press enter to accept default ",
         BRIGHT_WHITE, RED);
         TTY.PUT (19, 24, "                               ", YELLOW,
RED);
         CURSOR.SET_SIZE(13,13);
         loop
            CURSOR.MOVE (17, 50);
            TTY.GET (FIN_OPT_TYP, CHAR);
            if FIN_OPT_TYP = 2 or FIN_OPT_TYP = 3 or
            FIN_OPT_TYP = 4 or FIN_OPT_TYP = 28  then
               exit;
            else
               TTY.PUT (23, 24, " Improper input, please reenter ",
               BLUE, CYAN);
            end if;
         end loop;
         CURSOR.INHIBIT;

------------------------------------------------------------------------
--       Multiple Fin Problem, Rectangular Fins, No Optimization      --
------------------------------------------------------------------------
         if (FIN_OPT_TYP = 2) then
            MULTIPLE_NO_OPT(UNITS, CONVERT_DIST, CONVERT_TEMP, G_C,
            GRAVITY, WALL_LENGTH, WALL_LENGTH_UNITS, WALL_WIDTH,
            WALL_WIDTH_UNITS, LENGTH, LENGTH_UNITS, HEIGHT,
            HEIGHT_UNITS, WIDTH, WIDTH_UNITS, SPACING,
            SPACING_UNITS, NUM_FINS, NUM_FINS_UNITS, DENSITY,
            DENSITY_UNITS, SPECIFIC_HEAT, SPECIFIC_HEAT_UNITS, K,
            K_FLUID, K_UNITS, NU, NU_UNITS, T_AMBIENT, T_WALL,
            T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Multiple Fin Problem, Rectangular Fins, Maximum Heat          --
--      Transfer Capability From Each Fin in a Given area             --
------------------------------------------------------------------------
         elsif (FIN_OPT_TYP = 3) then
            MULTIPLE_MAX_FIN(UNITS, CONVERT_DIST, CONVERT_TEMP, G_C,
            GRAVITY, WALL_LENGTH, WALL_LENGTH_UNITS, WALL_WIDTH,
            WALL_WIDTH_UNITS, LENGTH, LENGTH_UNITS, HEIGHT,
            HEIGHT_UNITS, WIDTH, WIDTH_UNITS, SPACING,
            SPACING_UNITS, NUM_FINS, NUM_FINS_UNITS, DENSITY,
            DENSITY_UNITS, SPECIFIC_HEAT, SPECIFIC_HEAT_UNITS, K,
            K_FLUID, K_UNITS, NU, NU_UNITS, T_AMBIENT, T_WALL,
            T_UNITS, Q, Q_UNITS);

------------------------------------------------------------------------
--      Single Fin Problem, Rectangular Fin, Maximum Heat Transfer    --
--                   Capability for a Given Area                      --
------------------------------------------------------------------------
         else
            MULTIPLE_MAX_Q(UNITS, CONVERT_DIST, CONVERT_TEMP, G_C,
            GRAVITY, WALL_LENGTH, WALL_LENGTH_UNITS, WALL_WIDTH,
            WALL_WIDTH_UNITS, LENGTH, LENGTH_UNITS, HEIGHT,
            HEIGHT_UNITS, WIDTH, WIDTH_UNITS, SPACING,
            SPACING_UNITS, NUM_FINS, NUM_FINS_UNITS, DENSITY,
            DENSITY_UNITS, SPECIFIC_HEAT, SPECIFIC_HEAT_UNITS, K,
            K_FLUID, K_UNITS, NU, NU_UNITS, T_AMBIENT, T_WALL,
            T_UNITS, Q, Q_UNITS);
         end if;

-----------------------------------------------------------------------
--                 Multiple Fin Problem, Rectangular Fins,           --
--             Draw Rectangular Fins With Calculated Dimensions      --
-----------------------------------------------------------------------
         PUT (WIDTH_MSG(1..10), WIDTH, 4, 3);
         WIDTH_MSG(11) := ' ';
         WIDTH_MSG(12..13) := WIDTH_UNITS;
         PUT (LENGTH_MSG(1..10), LENGTH, 4, 3);
         LENGTH_MSG(11) := ' ';
         LENGTH_MSG(12..13) := LENGTH_UNITS;
         PUT (HEIGHT_MSG(1..10), HEIGHT, 4, 3);
         HEIGHT_MSG(11) := ' ';
         HEIGHT_MSG(12..13) := HEIGHT_UNITS;
         PUT (SPACING_MSG(1..10), SPACING, 4, 3);
         SPACING_MSG(11) := ' ';
         SPACING_MSG(12..13) := SPACING_UNITS;
         PUT (WALL_LENGTH_MSG(1..10), WALL_LENGTH, 4, 3);
         WALL_LENGTH_MSG(11) := ' ';
         WALL_LENGTH_MSG(12..13) := WALL_LENGTH_UNITS;
         PUT (WALL_WIDTH_MSG(1..10), WALL_WIDTH, 4, 3);
         WALL_WIDTH_MSG(11) := ' ';
         WALL_WIDTH_MSG(12..13) := WALL_WIDTH_UNITS;
         FINOPT_DRAWINGS.MULTI_FIN_DRAWING(WIDTH_MSG, LENGTH_MSG,
         HEIGHT_MSG, SPACING_MSG, WALL_LENGTH_MSG, WALL_WIDTH_MSG);
      end if;

-----------------------------------------------------------------------
--                        Reinitialize Variables                     --
-----------------------------------------------------------------------
      if (UNITS = 2) then
         SPACING_ENGLISH := SPACING;
         DENSITY_ENGLISH := DENSITY;
         SPECIFIC_HEAT_ENGLISH := SPECIFIC_HEAT;
         NU_ENGLISH := NU;
         K_FLUID_ENGLISH := K_FLUID;
         WALL_LENGTH_ENGLISH := WALL_LENGTH;
         WALL_WIDTH_ENGLISH := WALL_WIDTH;
         NUM_FINS_ENGLISH := NUM_FINS;
         DIAMETER_ENGLISH := DIAMETER;
         HEIGHT_ENGLISH := HEIGHT;
         WIDTH_ENGLISH := WIDTH;
         LENGTH_ENGLISH := LENGTH;
         VOLUME_ENGLISH := VOLUME;
         H_ENGLISH := H;
         K_ENGLISH := K;
         T_AMBIENT_ENGLISH := T_AMBIENT;
         T_WALL_ENGLISH := T_WALL;
         Q_ENGLISH := Q;
      else
         SPACING_SI := SPACING;
         DENSITY_SI := DENSITY;
         SPECIFIC_HEAT_SI := SPECIFIC_HEAT;
         NU_SI := NU;
         K_FLUID_SI := K_FLUID;
         WALL_LENGTH_SI := WALL_LENGTH;
         WALL_WIDTH_SI := WALL_WIDTH;
         NUM_FINS_SI := NUM_FINS;
         DIAMETER_SI := DIAMETER;
         HEIGHT_SI := HEIGHT;
         WIDTH_SI := WIDTH;
         LENGTH_SI := LENGTH;
         VOLUME_SI := VOLUME;
         H_SI := H;
         K_SI := K;
         T_AMBIENT_SI := T_AMBIENT;
         T_WALL_SI := T_WALL;
         Q_SI := Q;
       end if;
   end loop;

------------------------------------------------------------------------
--                          Exit to DOS                               --
------------------------------------------------------------------------
   FINOPT_PICTURES.EXIT_MSG;
   VIDEO.SET_COLOR_PALETTE (BLACK);
   CURSOR.MOVE (22, 1);
   CURSOR.SET_SIZE(13,13);
end FINOPT;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :             A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

package FINOPT_COMMON is

   procedure GET_INPUT(INPUT_VALUE                 : in out FLOAT;
                       INPUT_MSG                   : in STRING;
                       SIZE_INPUT_MSG              : in INTEGER;
                       INPUT_VALUE_UNITS           : in STRING;
                       SIZE_INPUT_VALUE_UNITS      : in INTEGER;
                       ROW_START                   : in INTEGER);

end FINOPT_COMMON;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :              A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    TEXT_IO, COMMON_DISPLAY_TYPES, TTY, CURSOR;

use     TEXT_IO, COMMON_DISPLAY_TYPES;

package body FINOPT_COMMON is

   package FLOAT_INOUT is new FLOAT_IO(FLOAT);
   use FLOAT_INOUT;

   procedure GET_INPUT(INPUT_VALUE                  : in out FLOAT;
                       INPUT_MSG                    : in STRING;
                       SIZE_INPUT_MSG               : in INTEGER;
                       INPUT_VALUE_UNITS            : in STRING;
                       SIZE_INPUT_VALUE_UNITS       : in INTEGER;
                       ROW_START                    : in INTEGER) is

      NUMBER_OUT                                    : STRING(1..10);

      CHAR                                          : CHARACTER;

      DEFAULT_KEY                                   : INTEGER;

   begin
      TTY.PUT (ROW_START, 1, INPUT_MSG, YELLOW, BLACK);
      TTY.PUT (ROW_START, 1+SIZE_INPUT_MSG, " (", YELLOW, BLACK);
      TTY.PUT (ROW_START, 3+SIZE_INPUT_MSG,
      INPUT_VALUE_UNITS(1..SIZE_INPUT_VALUE_UNITS), YELLOW, BLACK);
      TTY.PUT (ROW_START, SIZE_INPUT_VALUE_UNITS+3+SIZE_INPUT_MSG, ") =
",
      YELLOW, BLACK);
      TTY.PUT (ROW_START+1, 1,
      "Press enter to accept default or any other key to enter new
value",
      BRIGHT_WHITE, BLACK);
      PUT (NUMBER_OUT, INPUT_VALUE, 4, 3);
      TTY.PUT (ROW_START, SIZE_INPUT_VALUE_UNITS+7+SIZE_INPUT_MSG,
      NUMBER_OUT, YELLOW, BLACK);
--      CURSOR.SET_SIZE (13,13);
      TTY.GET (DEFAULT_KEY, CHAR);
--      CURSOR.INHIBIT;
      if DEFAULT_KEY /= 28  then
         loop
            begin
               TTY.PUT (ROW_START,
SIZE_INPUT_VALUE_UNITS+7+SIZE_INPUT_MSG,
               "          ", BLACK, BLACK);
               TTY.PUT (ROW_START+2, 1, "New value = ", BRIGHT_WHITE,
BLACK);
               CURSOR.SET_SIZE (13,13);
               GET (INPUT_VALUE);
               SKIP_LINE;
               CURSOR.INHIBIT;
               exit;
            exception
               when others =>
                  TTY.PUT (23, 24, " Improper input, please reenter ",
                  BLUE, CYAN);
               end;
         end loop;
         TTY.PUT (23, 24, "                                 ",
         BLACK, BLACK);
         TTY.PUT (ROW_START+2, 1, "                                   ",
         BLACK, BLACK);
      end if;
      TTY.PUT (ROW_START+1, 1,
      "
",
      BLACK, BLACK);
      TTY.PUT (ROW_START, 1+SIZE_INPUT_MSG, "
",
      YELLOW, BLACK);
      TTY.PUT (ROW_START, 46, "      ", BLACK, BLACK);
      TTY.PUT (ROW_START, 45, " = ", YELLOW, BLACK);
      PUT (NUMBER_OUT, INPUT_VALUE, 4, 3);
      TTY.PUT (ROW_START, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (ROW_START, 58, " ", YELLOW, BLACK);
      TTY.PUT (ROW_START, 59,
INPUT_VALUE_UNITS(1..SIZE_INPUT_VALUE_UNITS),
      YELLOW, BLACK);
      TTY.PUT (ROW_START, 59+SIZE_INPUT_VALUE_UNITS,
      "                          ", YELLOW, BLACK);

   end GET_INPUT;

end FINOPT_COMMON;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :                A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

package FINOPT_DRAWINGS is

   procedure CYLINDRICAL_DRAWING(DIAMETER_MSG           : in STRING;
                                 HEIGHT_MSG             : in STRING);

   procedure RECTANGULAR_DRAWING(WIDTH_MSG              : in STRING;
                                 LENGTH_MSG             : in STRING;
                                 HEIGHT_MSG             : in STRING);

   procedure MULTI_FIN_DRAWING(WIDTH_MSG                : in STRING;
                               LENGTH_MSG               : in STRING;
                               HEIGHT_MSG               : in STRING;
                               SPACING_MSG              : in STRING;
                               WALL_LENGTH_MSG          : in STRING;
                               WALL_WIDTH_MSG           : in STRING);

end FINOPT_DRAWINGS;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :              A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    COMMON_DISPLAY_TYPES, TTY;

use     COMMON_DISPLAY_TYPES;

package body FINOPT_DRAWINGS is

   procedure CYLINDRICAL_DRAWING(DIAMETER_MSG           : in STRING;
                                 HEIGHT_MSG             : in STRING) is

      PAUSE                                             : INTEGER;

      CHAR                                              : CHARACTER;

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT ( 0, 20, "____", YELLOW, BLACK);
      TTY.PUT ( 1, 18, "/", YELLOW, BLACK);
      TTY.PUT ( 1, 19, "   / |", YELLOW, RED);
      TTY.PUT ( 2, 16, "/", YELLOW, BLACK);
      TTY.PUT ( 2, 17, "   /   |", YELLOW, RED);
      TTY.PUT ( 3, 14, "/", YELLOW, BLACK);
      TTY.PUT ( 3, 15, "   /     |", YELLOW, RED);
      TTY.PUT ( 4, 12, "/", YELLOW, BLACK);
      TTY.PUT ( 4, 13, "   /       |", YELLOW, RED);
      TTY.PUT ( 5, 10, "/", YELLOW, BLACK);
      TTY.PUT ( 5, 11, "   /         |", YELLOW, RED);
      TTY.PUT ( 6,  8, "/", YELLOW, BLACK);
      TTY.PUT ( 6,  9, "   /           |", YELLOW, RED);
      TTY.PUT ( 7,  6, "/", YELLOW, BLACK);
      TTY.PUT ( 7,  7, "__ /             |", YELLOW, RED);
      TTY.PUT ( 8,  5, "|   |        __ ____", YELLOW, RED);
      TTY.PUT ( 8, 25, "_____________________ __    __________",
      YELLOW, BLACK);
      TTY.PUT ( 9,  5, "|   |      /    \                       /    ",
      YELLOW, RED);
      TTY.PUT ( 9, 50, "\       |", YELLOW, BLACK);
      TTY.PUT (10,  5, "|   |    /        \                   /
",
      YELLOW, RED);
      TTY.PUT (10, 52, "\     |", YELLOW, BLACK);
      TTY.PUT (11,  5, "|   |   |          |       FIN       |
|",
      YELLOW, RED);
      TTY.PUT (11, 54, "    |", YELLOW, BLACK);
      TTY.PUT (11, 61, DIAMETER_MSG, YELLOW, BLACK);
      TTY.PUT (12,  5, "|   |   |          |                 |
|",
      YELLOW, RED);
      TTY.PUT (12, 54, "    |", YELLOW, BLACK);
      TTY.PUT (13,  5, "| W |    \        /                   \
",
      YELLOW, RED);
      TTY.PUT (13, 52, "/     |", YELLOW, BLACK);
      TTY.PUT (14,  5, "| A |      \ __ /_______________________\ __ ",
      YELLOW, RED);
      TTY.PUT (14, 50, "/  _____|___", YELLOW, BLACK);
      TTY.PUT (15,  5, "| L |            ", YELLOW, RED);
      TTY.PUT (15, 22, "/", YELLOW, BLACK);
      TTY.PUT (16,  5, "| L |         |", YELLOW, RED);
      TTY.PUT (16, 20, "/                           |", YELLOW, BLACK);
      TTY.PUT (17,  5, "|   |        ", YELLOW, RED);
      TTY.PUT (17, 18, "/|                            |", YELLOW,
BLACK);
      TTY.PUT (18,  5, "|   |      ", YELLOW, RED);
      TTY.PUT (18, 16, "/  |----------------------------|", YELLOW,
BLACK);
      TTY.PUT (19,  5, "|   |    ", YELLOW, RED);
      TTY.PUT (19, 14, "/    |                            |", YELLOW,
BLACK);
      TTY.PUT (19, 28, HEIGHT_MSG, YELLOW, BLACK);
      TTY.PUT (20,  5, "|   |  ", YELLOW, RED);
      TTY.PUT (20, 12, "/      |                            |",
      YELLOW, BLACK);
      TTY.PUT (21,  5, "|___|", YELLOW, RED);
      TTY.PUT (21, 10, "/", YELLOW, BLACK);
      TTY.PUT (23, 27, "  Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end CYLINDRICAL_DRAWING;

   procedure RECTANGULAR_DRAWING(WIDTH_MSG          : in STRING;
                                 LENGTH_MSG             : in STRING;
                                 HEIGHT_MSG            : in STRING) is

      PAUSE                                             : INTEGER;

      CHAR                                              : CHARACTER;

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT ( 0, 25, "______", YELLOW, BLACK);
      TTY.PUT ( 1, 23, "/", YELLOW, BLACK);
      TTY.PUT ( 1, 24, "     / |", YELLOW, RED);
      TTY.PUT ( 2, 21, "/", YELLOW, BLACK);
      TTY.PUT ( 2, 22, "     /   |", YELLOW, RED);
      TTY.PUT ( 3, 19, "/", YELLOW, BLACK);
      TTY.PUT ( 3, 20, "     /     |", YELLOW, RED);
      TTY.PUT ( 4, 17, "/", YELLOW, BLACK);
      TTY.PUT ( 4, 18, "     /       |", YELLOW, RED);
      TTY.PUT ( 4, 32, "_________________  _____", YELLOW, BLACK);
      TTY.PUT ( 5, 15, "/", YELLOW, BLACK);
      TTY.PUT ( 5, 16, "____ /         /              / |", YELLOW,
RED);
      TTY.PUT ( 5, 53, "|", YELLOW, BLACK);
      TTY.PUT ( 6, 14, "|     |        /              /   |", YELLOW,
RED);
      TTY.PUT ( 6, 53, "|", YELLOW, BLACK);
      TTY.PUT ( 6, 56, WIDTH_MSG, YELLOW, BLACK);
      TTY.PUT ( 7, 14, "|     |      /              /     |", YELLOW,
RED);
      TTY.PUT ( 7, 51, "__|__", YELLOW, BLACK);
      TTY.PUT ( 8, 14, "|     |    /              /     ", YELLOW, RED);
      TTY.PUT ( 8, 46, "/", YELLOW, BLACK);
      TTY.PUT ( 9, 14, "|     |  /              /     ", YELLOW, RED);
      TTY.PUT ( 9, 44, "/   |", YELLOW, BLACK);
      TTY.PUT (10, 14, "|  W  |/_____________ /     ", YELLOW, RED);
      TTY.PUT (10, 42, "/     |", YELLOW, BLACK);
      TTY.PUT (11, 14, "|  A                 |    ", YELLOW, RED);
      TTY.PUT (11, 40, "/       |", YELLOW, BLACK);
      TTY.PUT (12, 14, "|  L        FIN      |  ", YELLOW, RED);
      TTY.PUT (12, 38, "/        /|", YELLOW, BLACK);
      TTY.PUT (13, 14, "|  L   ______________|", YELLOW, RED);
      TTY.PUT (13, 36, "/        /  |", YELLOW, BLACK);
      TTY.PUT (14, 14, "|     |      ", YELLOW, RED);
      TTY.PUT (14, 27, "/               /    |", YELLOW, BLACK);
      TTY.PUT (15, 14, "|     |    ", YELLOW, RED);
      TTY.PUT (15, 25, "/         |     /      |", YELLOW, BLACK);
      TTY.PUT (16, 14, "|     |  ", YELLOW, RED);
      TTY.PUT (16, 23, "/           |   /", YELLOW, BLACK);
      TTY.PUT (17, 14, "|_____|", YELLOW, RED);
      TTY.PUT (17, 21, "/             | /", YELLOW, BLACK);
      TTY.PUT (17, 41, LENGTH_MSG, YELLOW, BLACK);
      TTY.PUT (18, 35, "|", YELLOW, BLACK);
      TTY.PUT (19, 20, "|              |", YELLOW, BLACK);
      TTY.PUT (20, 20, "|--------------|", YELLOW, BLACK);
      TTY.PUT (21, 20, "|", YELLOW, BLACK);
      TTY.PUT (21, 22, HEIGHT_MSG, YELLOW, BLACK);
      TTY.PUT (21, 35, "|", YELLOW, BLACK);
      TTY.PUT (23, 27, "  Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end RECTANGULAR_DRAWING;

   procedure MULTI_FIN_DRAWING(WIDTH_MSG          : in STRING;
                               LENGTH_MSG              : in STRING;
                               HEIGHT_MSG             : in STRING;
                               SPACING_MSG            : in STRING;
                               WALL_LENGTH_MSG         : in STRING;
                               WALL_WIDTH_MSG         : in STRING) is

      PAUSE                                             : INTEGER;

      CHAR                                              : CHARACTER;

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT ( 0, 27, WALL_WIDTH_MSG, YELLOW, BLACK);
      TTY.PUT ( 1, 10,
      "|-----------------------------------------------|", YELLOW,
BLACK);
      TTY.PUT ( 2,  6,
      "___  _______________________________________________",
      YELLOW, BLACK);
      TTY.PUT ( 3,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 3, 10,
      "|    ___         ___         ___                |", YELLOW, RED);
      TTY.PUT ( 4,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 4, 10,
      "|   |\  \       |\  \       |\  \               |", YELLOW, RED);
      TTY.PUT ( 5,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 5, 10,
      "|   |  \  \     |  \  \     |  \  \     WALL    |", YELLOW, RED);
      TTY.PUT ( 6,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 6, 10,
      "|   |    \  \   |    \  \   |    \  \           |", YELLOW, RED);
      TTY.PUT ( 7,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 7, 10,
      "|   |      \  \ |      \  \ |      \  \         |", YELLOW, RED);
      TTY.PUT ( 8,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 8, 10,
      "|   |        \  \        \  \        \  \       |", YELLOW, RED);
      TTY.PUT ( 9,  7, "|", YELLOW, BLACK);
      TTY.PUT ( 9, 10,
      "|   |          \ _\        \ _\        \ _\   __|", YELLOW, RED);
      TTY.PUT ( 9, 59, "_____", YELLOW, BLACK);
      TTY.PUT (10,  7, "|", YELLOW, BLACK);
      TTY.PUT (10, 10,
      "|   |     F     |  |        |  |        |  |    |", YELLOW, RED);
      TTY.PUT (10, 62, "|", YELLOW, BLACK);
      TTY.PUT (11,  7, "|", YELLOW, BLACK);
      TTY.PUT (11, 10,
      "|   |     I     |  |        |  |        |  |    |", YELLOW, RED);
      TTY.PUT (11, 62, "|", YELLOW, BLACK);
      TTY.PUT (12,  7, "|", YELLOW, BLACK);
      TTY.PUT (12, 10,
      "|    \    N     |  |        |  |        |  |    |", YELLOW, RED);
      TTY.PUT (12, 62, "|", YELLOW, BLACK);
      TTY.PUT (13,  7, "|", YELLOW, BLACK);
      TTY.PUT (13, 10,
      "|      \        |  |        |  |        |  |    |", YELLOW, RED);
      TTY.PUT (13, 62, "|", YELLOW, BLACK);
      TTY.PUT (13, 64, LENGTH_MSG, YELLOW, BLACK);
      TTY.PUT (14,  7, "|", YELLOW, BLACK);
      TTY.PUT (14, 10,
      "|   |    \      |  | \      |  | \      |  |    |", YELLOW, RED);
      TTY.PUT (14, 62, "|", YELLOW, BLACK);
      TTY.PUT (15,  6, "_|_", YELLOW, BLACK);
      TTY.PUT (15, 10,
      "|___|_\____\    |  |___\    |  |___\    |  |____|", YELLOW, RED);
      TTY.PUT (15, 62, "|", YELLOW, BLACK);
      TTY.PUT (16, 14, "|   \    \", YELLOW, BLACK);
      TTY.PUT (16, 24, "  |  |", YELLOW, RED);
      TTY.PUT (16, 35, "\", YELLOW, BLACK);
      TTY.PUT (16, 36, "  |  |", YELLOW, RED);
      TTY.PUT (16, 47, "\", YELLOW, BLACK);
      TTY.PUT (16, 48, "  |  |", YELLOW, RED);
      TTY.PUT (16, 62, "|", YELLOW, BLACK);
      TTY.PUT (17, 20, "\    \", YELLOW, BLACK);
      TTY.PUT (17, 26, "|__|", YELLOW, RED);
      TTY.PUT (17, 37, "\", YELLOW, BLACK);
      TTY.PUT (17, 38, "|__|", YELLOW, RED);
      TTY.PUT (17, 49, "\", YELLOW, BLACK);
      TTY.PUT (17, 50, "|__|", YELLOW, RED);
      TTY.PUT (17, 56, "______|_", YELLOW, BLACK);
      TTY.PUT (18,  7, HEIGHT_MSG, YELLOW, BLACK);
      TTY.PUT (18, 22, "\", YELLOW, BLACK);
      TTY.PUT (19, 24, "\ |  |--------|           |--|", YELLOW, BLACK);
      TTY.PUT (20, 26, "|", YELLOW, BLACK);
      TTY.PUT (20, 28, SPACING_MSG, YELLOW, BLACK);
      TTY.PUT (20, 45, WIDTH_MSG, YELLOW, BLACK);
      TTY.PUT (21, 26, "|", YELLOW, BLACK);
      TTY.PUT ( 3,  4, WALL_LENGTH_MSG(1), YELLOW, BLACK);
      TTY.PUT ( 4,  4, WALL_LENGTH_MSG(2), YELLOW, BLACK);
      TTY.PUT ( 5,  4, WALL_LENGTH_MSG(3), YELLOW, BLACK);
      TTY.PUT ( 6,  4, WALL_LENGTH_MSG(4), YELLOW, BLACK);
      TTY.PUT ( 7,  4, WALL_LENGTH_MSG(5), YELLOW, BLACK);
      TTY.PUT ( 8,  4, WALL_LENGTH_MSG(6), YELLOW, BLACK);
      TTY.PUT ( 9,  4, WALL_LENGTH_MSG(7), YELLOW, BLACK);
      TTY.PUT (10,  4, WALL_LENGTH_MSG(8), YELLOW, BLACK);
      TTY.PUT (11,  4, WALL_LENGTH_MSG(9), YELLOW, BLACK);
      TTY.PUT (12,  4, WALL_LENGTH_MSG(10), YELLOW, BLACK);
      TTY.PUT (13,  4, WALL_LENGTH_MSG(11), YELLOW, BLACK);
      TTY.PUT (14,  4, WALL_LENGTH_MSG(12), YELLOW, BLACK);
      TTY.PUT (15,  4, WALL_LENGTH_MSG(13), YELLOW, BLACK);
      TTY.PUT (23, 27, "  Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);
    end MULTI_FIN_DRAWING;

end FINOPT_DRAWINGS;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :              A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

package FINOPT_MULTIPLE is

   procedure MULTIPLE_NO_OPT(UNITS                    : in INTEGER;
                             CONVERT_DIST             : in FLOAT;
                             CONVERT_TEMP             : in FLOAT;
                             G_C                      : in FLOAT;
                             GRAVITY                  : in FLOAT;
                             WALL_LENGTH              : in out FLOAT;
                             WALL_LENGTH_UNITS        : in STRING;
                             WALL_WIDTH               : in out FLOAT;
                             WALL_WIDTH_UNITS         : in STRING;
                             LENGTH                   : in out FLOAT;
                             LENGTH_UNITS             : in STRING;
                             HEIGHT                   : in out FLOAT;
                             HEIGHT_UNITS             : in STRING;
                             WIDTH                    : in out FLOAT;
                             WIDTH_UNITS              : in STRING;
                             SPACING                  : in out FLOAT;
                             SPACING_UNITS            : in STRING;
                             NUM_FINS                 : in out FLOAT;
                             NUM_FINS_UNITS           : in STRING;
                             DENSITY                  : in out FLOAT;
                             DENSITY_UNITS            : in STRING;
                             SPECIFIC_HEAT            : in out FLOAT;
                             SPECIFIC_HEAT_UNITS      : in STRING;
                             K                        : in out FLOAT;
                             K_FLUID                  : in out FLOAT;
                             K_UNITS                  : in STRING;
                             NU                       : in out FLOAT;
                             NU_UNITS                 : in STRING;
                             T_AMBIENT                : in out FLOAT;
                             T_WALL                   : in out FLOAT;
                             T_UNITS                  : in STRING;
                             Q                        : in out FLOAT;
                             Q_UNITS                  : in STRING);

   procedure MULTIPLE_MAX_FIN(UNITS                    : in INTEGER;
                              CONVERT_DIST             : in FLOAT;
                              CONVERT_TEMP             : in FLOAT;
                              G_C                      : in FLOAT;
                              GRAVITY                  : in FLOAT;
                              WALL_LENGTH              : in out FLOAT;
                              WALL_LENGTH_UNITS        : in STRING;
                              WALL_WIDTH               : in out FLOAT;
                              WALL_WIDTH_UNITS         : in STRING;
                              LENGTH                   : in out FLOAT;
                              LENGTH_UNITS             : in STRING;
                              HEIGHT                   : in out FLOAT;
                              HEIGHT_UNITS             : in STRING;
                              WIDTH                    : in out FLOAT;
                              WIDTH_UNITS              : in STRING;
                              SPACING                  : in out FLOAT;
                              SPACING_UNITS            : in STRING;
                              NUM_FINS                 : in out FLOAT;
                              NUM_FINS_UNITS           : in STRING;
                              DENSITY                  : in out FLOAT;
                              DENSITY_UNITS            : in STRING;
                              SPECIFIC_HEAT            : in out FLOAT;
                              SPECIFIC_HEAT_UNITS      : in STRING;
                              K                        : in out FLOAT;
                              K_FLUID                  : in out FLOAT;
                              K_UNITS                  : in STRING;
                              NU                       : in out FLOAT;
                              NU_UNITS                 : in STRING;
                              T_AMBIENT                : in out FLOAT;
                              T_WALL                   : in out FLOAT;
                              T_UNITS                  : in STRING;
                              Q                        : in out FLOAT;
                              Q_UNITS                  : in STRING);

   procedure MULTIPLE_MAX_Q(UNITS                    : in INTEGER;
                            CONVERT_DIST             : in FLOAT;
                            CONVERT_TEMP             : in FLOAT;
                            G_C                      : in FLOAT;
                            GRAVITY                  : in FLOAT;
                            WALL_LENGTH              : in out FLOAT;
                            WALL_LENGTH_UNITS        : in STRING;
                            WALL_WIDTH               : in out FLOAT;
                            WALL_WIDTH_UNITS         : in STRING;
                            LENGTH                   : in out FLOAT;
                            LENGTH_UNITS             : in STRING;
                            HEIGHT                   : in out FLOAT;
                            HEIGHT_UNITS             : in STRING;
                            WIDTH                    : in out FLOAT;
                            WIDTH_UNITS              : in STRING;
                            SPACING                  : in out FLOAT;
                            SPACING_UNITS            : in STRING;
                            NUM_FINS                 : in out FLOAT;
                            NUM_FINS_UNITS           : in STRING;
                            DENSITY                  : in out FLOAT;
                            DENSITY_UNITS            : in STRING;
                            SPECIFIC_HEAT            : in out FLOAT;
                            SPECIFIC_HEAT_UNITS      : in STRING;
                            K                        : in out FLOAT;
                            K_FLUID                  : in out FLOAT;
                            K_UNITS                  : in STRING;
                            NU                       : in out FLOAT;
                            NU_UNITS                 : in STRING;
                            T_AMBIENT                : in out FLOAT;
                            T_WALL                   : in out FLOAT;
                            T_UNITS                  : in STRING;
                            Q                        : in out FLOAT;
                            Q_UNITS                  : in STRING);

end FINOPT_MULTIPLE;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :              A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    TEXT_IO, COMMON_DISPLAY_TYPES, TTY, CURSOR, FINOPT_COMMON,
        GENERIC_ELEMENTARY_FUNCTIONS, FINOPT_PICTURES;

use     TEXT_IO, COMMON_DISPLAY_TYPES, FINOPT_COMMON;

package body FINOPT_MULTIPLE is

   package FLOAT_INOUT is new FLOAT_IO(FLOAT);
   package MY_ELEMENTARY_FUNCTIONS is
           new GENERIC_ELEMENTARY_FUNCTIONS(FLOAT);
   use FLOAT_INOUT, MY_ELEMENTARY_FUNCTIONS;

   procedure MULTIPLE_NO_OPT(UNITS                    : in INTEGER;
                             CONVERT_DIST             : in FLOAT;
                             CONVERT_TEMP             : in FLOAT;
                             G_C                      : in FLOAT;
                             GRAVITY                  : in FLOAT;
                             WALL_LENGTH              : in out FLOAT;
                             WALL_LENGTH_UNITS        : in STRING;
                             WALL_WIDTH               : in out FLOAT;
                             WALL_WIDTH_UNITS         : in STRING;
                             LENGTH                   : in out FLOAT;
                             LENGTH_UNITS             : in STRING;
                             HEIGHT                   : in out FLOAT;
                             HEIGHT_UNITS             : in STRING;
                             WIDTH                    : in out FLOAT;
                             WIDTH_UNITS              : in STRING;
                             SPACING                  : in out FLOAT;
                             SPACING_UNITS            : in STRING;
                             NUM_FINS                 : in out FLOAT;
                             NUM_FINS_UNITS           : in STRING;
                             DENSITY                  : in out FLOAT;
                             DENSITY_UNITS            : in STRING;
                             SPECIFIC_HEAT            : in out FLOAT;
                             SPECIFIC_HEAT_UNITS      : in STRING;
                             K                        : in out FLOAT;
                             K_FLUID                  : in out FLOAT;
                             K_UNITS                  : in STRING;
                             NU                       : in out FLOAT;
                             NU_UNITS                 : in STRING;
                             T_AMBIENT                : in out FLOAT;
                             T_WALL                   : in out FLOAT;
                             T_UNITS                  : in STRING;
                             Q                        : in out FLOAT;
                             Q_UNITS                  : in STRING) is

      NUMBER_OUT                                      : STRING(1..10);

      CHAR                                            : CHARACTER;

      PAUSE, NUM_FINS_INT                             : INTEGER;
      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP, T_AVG, BETA, MU,
      RAYLEIGH_CHANNEL, NUSSELT_CHANNEL, H,
      AREA_BASE, AREA_FIN, AREA_TOTAL                 : FLOAT;

   begin

--------------------------------------------------------------------
--                            Inputs                              --
--------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(WALL_LENGTH, "Length of the fin placement area", 32,
      WALL_LENGTH_UNITS, 2, 13);
      GET_INPUT(WALL_WIDTH, "Width of the fin placement area", 31,
      WALL_WIDTH_UNITS, 2, 14);
      GET_INPUT(LENGTH, "Length of each fin", 18, LENGTH_UNITS, 2, 15);
      GET_INPUT(HEIGHT, "Height of each fin", 18, HEIGHT_UNITS, 2, 16);
      GET_INPUT(WIDTH, "Width of each fin", 17, WIDTH_UNITS, 2, 17);
      GET_INPUT(SPACING, "Spacing between fins", 20, SPACING_UNITS, 2,
18);
      NUM_FINS := (WALL_WIDTH-WIDTH)/(SPACING+WIDTH);
      NUM_FINS := NUM_FINS-0.49999999999;
      NUM_FINS_INT := INTEGER(NUM_FINS);
      NUM_FINS_INT := NUM_FINS_INT+1;
      NUM_FINS := FLOAT(NUM_FINS_INT);
      GET_INPUT(NUM_FINS, "Number of fins, default is maximum number",
      41, NUM_FINS_UNITS, 4, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);
      FINOPT_PICTURES.INPUT_CONT_MSG;
      if (UNITS = 2) then
         GET_INPUT(DENSITY, "Density of surrounding fluid",
         28, DENSITY_UNITS, 8, 13);
      else
         GET_INPUT(DENSITY, "Density of surrounding fluid",
         28, DENSITY_UNITS, 6, 13);
      end if;
      if (UNITS = 2) then
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 15, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 17, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 6, 17);
      else
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 12, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 11, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 5, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19, T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16, T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--   Calculations (Assume Tip is Insulated) and Length >> Width       --
------------------------------------------------------------------------
      T_AVG := (T_WALL+T_AMBIENT)/2.0;
      BETA := 1.0/(T_AVG+CONVERT_TEMP);
      DELTA_T := T_WALL-T_AMBIENT;
      MU := (NU*DENSITY)/G_C;
      RAYLEIGH_CHANNEL := ((DENSITY**2)*GRAVITY*BETA*SPECIFIC_HEAT
      *((SPACING/CONVERT_DIST)**4)*DELTA_T)/(MU*(LENGTH/CONVERT_DIST)
      *K_FLUID);
      NUSSELT_CHANNEL := ((576.0/(RAYLEIGH_CHANNEL**2))
      +(2.873/SQRT(RAYLEIGH_CHANNEL)))**(-0.5);
      H := (NUSSELT_CHANNEL*K_FLUID)/(SPACING/CONVERT_DIST);
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      AREA_BASE :=
((WALL_WIDTH/CONVERT_DIST)*(WALL_LENGTH/CONVERT_DIST))
      -(NUM_FINS*(LENGTH/CONVERT_DIST)*(WIDTH/CONVERT_DIST));
      AREA_FIN := NUM_FINS*(2.0*(HEIGHT/CONVERT_DIST)
      *(LENGTH/CONVERT_DIST));
      AREA_TOTAL := AREA_BASE+(EFFICIENCY*AREA_FIN);
      Q := H*AREA_TOTAL*DELTA_T;
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

------------------------------------------------------------------------
--                       Outputs                                      --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Length of the fin placement area             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WALL_LENGTH, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, WALL_LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Width of the fin placement area              = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WALL_WIDTH, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, WALL_WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Length of each fin                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, LENGTH, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Height of each fin                           = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, HEIGHT, 4, 3);
TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (10, 59, HEIGHT_UNITS, YELLOW, BLACK);
TTY.PUT (11, 1, "Width of each fin                            = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, WIDTH, 4, 3);
TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (11, 59, WIDTH_UNITS, YELLOW, BLACK);
TTY.PUT (12, 1, "Spacing between fins                         = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, SPACING, 4, 3);
TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (12, 59, SPACING_UNITS, YELLOW, BLACK);
TTY.PUT (13, 1, "Number of fins                               = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, NUM_FINS, 4, 3);
TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (13, 59, NUM_FINS_UNITS, YELLOW, BLACK);
TTY.PUT (14, 1, "Density of surrounding fluid                 = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, DENSITY, 4, 3);
TTY.PUT (14, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (14, 59, DENSITY_UNITS, YELLOW, BLACK);
TTY.PUT (15, 1, "Specific heat of surrounding fluid           = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, SPECIFIC_HEAT, 4, 3);
TTY.PUT (15, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (15, 59, SPECIFIC_HEAT_UNITS, YELLOW, BLACK);
TTY.PUT (16, 1, "Thermal conductivity of material, k          = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, K, 4, 3);
TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (16, 59, K_UNITS, YELLOW, BLACK);
TTY.PUT (17, 1, "Thermal conductivity of surrounding fluid, k = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, K_FLUID, 4, 3);
TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (17, 59, K_UNITS, YELLOW, BLACK);
TTY.PUT (18, 1, "Kinematic viscosity of surrounding fluid     = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, NU, 4, 3);
TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (18, 59, NU_UNITS, YELLOW, BLACK);
TTY.PUT (19, 1, "Ambient Temperature                          = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
TTY.PUT (19, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (19, 59, T_UNITS, YELLOW, BLACK);
TTY.PUT (20, 1, "Wall Temperature                             = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, T_WALL, 4, 3);
TTY.PUT (20, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (20, 59, T_UNITS, YELLOW, BLACK);
TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
TTY.GET (PAUSE, CHAR);
```

```
       FINOPT_PICTURES.OUTPUT_CONT_MSG;
       TTY.PUT ( 6, 35, " Outputs ", BRIGHT_WHITE, GREEN);
       TTY.PUT ( 8, 1, "Heat transferred away by the fins, q         = ",
       YELLOW, BLACK);
       PUT (NUMBER_OUT, Q, 4, 3);
       TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
       TTY.PUT ( 8, 59, Q_UNITS, YELLOW, BLACK);
       TTY.PUT ( 9, 1, "The fin efficiency                           = ",
       YELLOW, BLACK);
       PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
       TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
       TTY.PUT (10, 1, "The temperature at the tip of the fins       = ",
       YELLOW, BLACK);
       PUT (NUMBER_OUT, T_TIP, 4, 3);
       TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
       TTY.PUT (10, 59, T_UNITS, YELLOW, BLACK);
       TTY.PUT (11, 1, "Channel Rayleigh number                      = ",
       YELLOW, BLACK);
       PUT (NUMBER_OUT, RAYLEIGH_CHANNEL, 4, 3);
       TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
       TTY.PUT (12, 1, "Channel Nusselt number                       = ",
       YELLOW, BLACK);
       PUT (NUMBER_OUT, NUSSELT_CHANNEL, 4, 3);
       TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
       TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
       TTY.GET (PAUSE, CHAR);

    end MULTIPLE_NO_OPT;

    procedure MULTIPLE_MAX_FIN(UNITS                    : in INTEGER;
                               CONVERT_DIST             : in FLOAT;
                               CONVERT_TEMP             : in FLOAT;
                               G_C                      : in FLOAT;
                               GRAVITY                  : in FLOAT;
                               WALL_LENGTH              : in out FLOAT;
                               WALL_LENGTH_UNITS        : in STRING;
                               WALL_WIDTH               : in out FLOAT;
                               WALL_WIDTH_UNITS         : in STRING;
                               LENGTH                   : in out FLOAT;
                               LENGTH_UNITS             : in STRING;
                               HEIGHT                   : in out FLOAT;
                               HEIGHT_UNITS             : in STRING;
                               WIDTH                    : in out FLOAT;
                               WIDTH_UNITS              : in STRING;
                               SPACING                  : in out FLOAT;
                               SPACING_UNITS            : in STRING;
                               NUM_FINS                 : in out FLOAT;
                               NUM_FINS_UNITS           : in STRING;
                               DENSITY                  : in out FLOAT;
                               DENSITY_UNITS            : in STRING;
                               SPECIFIC_HEAT            : in out FLOAT;
                               SPECIFIC_HEAT_UNITS      : in STRING;
                               K                        : in out FLOAT;
                               K_FLUID                  : in out FLOAT;
                               K_UNITS                  : in STRING;
                               NU                       : in out FLOAT;
```

```
                                    NU_UNITS                        : in STRING;
                                    T_AMBIENT                       : in out FLOAT;
                                    T_WALL                          : in out FLOAT;
                                    T_UNITS                         : in STRING;
                                    Q                               : in out FLOAT;
                                    Q_UNITS                         : in STRING) is

      NUMBER_OUT                                                    : STRING(1..10);

      CHAR                                                          : CHARACTER;

      PAUSE, NUM_FINS_INT                                           : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP, T_AVG, BETA, MU,
      RAYLEIGH_CHANNEL, NUSSELT_CHANNEL, H,
      AREA_BASE, AREA_FIN, AREA_TOTAL, P                            : FLOAT;

   begin

-------------------------------------------------------------------------
--                            Inputs                                  --
-------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(WALL_LENGTH, "Length of the fin placement area", 32,
      WALL_LENGTH_UNITS, 2, 14);
      GET_INPUT(WALL_WIDTH, "Width of the fin placement area", 31,
      WALL_WIDTH_UNITS, 2, 15);
      GET_INPUT(LENGTH, "Length of each fin", 18, LENGTH_UNITS, 2, 16);
      GET_INPUT(HEIGHT, "Height of each fin", 18, HEIGHT_UNITS, 2, 17);
      GET_INPUT(WIDTH, "Width of each fin", 17, WIDTH_UNITS, 2, 18);
      if (UNITS = 2) then
         GET_INPUT(DENSITY, "Density of surrounding fluid", 28,
         DENSITY_UNITS, 8, 19);
      else
         GET_INPUT(DENSITY, "Density of surrounding fluid", 28,
         DENSITY_UNITS, 6, 19);
      end if;
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);
      FINOPT_PICTURES.INPUT_CONT_MSG;
      if (UNITS = 2) then
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 15, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 17, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 6, 17);
      else
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 12, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 11, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 5, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19, T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16, T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--   Calculations (Assume Tip is Insulated) and Length >> Width        --
------------------------------------------------------------------------
      T_AVG := (T_WALL+T_AMBIENT)/2.0;
      BETA := 1.0/(T_AVG+CONVERT_TEMP);
      DELTA_T := T_WALL-T_AMBIENT;
      MU := (NU*DENSITY)/G_C;
      P := ((DENSITY**2)*GRAVITY*BETA*SPECIFIC_HEAT*DELTA_T)
      /(MU*(LENGTH/CONVERT_DIST)*K_FLUID);
      SPACING := CONVERT_DIST*(4.64/(P**(0.25)));
      NUM_FINS := (WALL_WIDTH-WIDTH)/(SPACING+WIDTH);
      NUM_FINS := NUM_FINS-0.49999999999;
      NUM_FINS_INT := INTEGER(NUM_FINS);
      NUM_FINS_INT := NUM_FINS_INT+1;
      NUM_FINS := FLOAT(NUM_FINS_INT);
      RAYLEIGH_CHANNEL := ((DENSITY**2)*GRAVITY*BETA*SPECIFIC_HEAT
      *((SPACING/CONVERT_DIST)**4)*DELTA_T)/(MU*(LENGTH/CONVERT_DIST)
      *K_FLUID);
      NUSSELT_CHANNEL := ((576.0/(RAYLEIGH_CHANNEL**2))
      +(2.873/SQRT(RAYLEIGH_CHANNEL)))**(-0.5);
      H := (NUSSELT_CHANNEL*K_FLUID)/(SPACING/CONVERT_DIST);
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      AREA_BASE :=
((WALL_WIDTH/CONVERT_DIST)*(WALL_LENGTH/CONVERT_DIST))
      -(NUM_FINS*(LENGTH/CONVERT_DIST)*(WIDTH/CONVERT_DIST));
      AREA_FIN := NUM_FINS*(2.0*(HEIGHT/CONVERT_DIST)
      *(LENGTH/CONVERT_DIST));
      AREA_TOTAL := AREA_BASE+(EFFICIENCY*AREA_FIN);
      Q := H*AREA_TOTAL*DELTA_T;
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

------------------------------------------------------------------------
--                       Outputs                                      --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Length of the fin placement area             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WALL_LENGTH, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, WALL_LENGTH_UNITS, YELLOW, BLACK);
TTY.PUT ( 8, 1, "Width of the fin placement area              = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, WALL_WIDTH, 4, 3);
TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT ( 8, 59, WALL_WIDTH_UNITS, YELLOW, BLACK);
TTY.PUT ( 9, 1, "Length of each fin                           = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, LENGTH, 4, 3);
TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT ( 9, 59, LENGTH_UNITS, YELLOW, BLACK);
TTY.PUT (10, 1, "Height of each fin                           = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, HEIGHT, 4, 3);
TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (10, 59, HEIGHT_UNITS, YELLOW, BLACK);
TTY.PUT (11, 1, "Width of each fin                            = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, WIDTH, 4, 3);
TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (11, 59, WIDTH_UNITS, YELLOW, BLACK);
TTY.PUT (12, 1, "Density of surrounding fluid                 = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, DENSITY, 4, 3);
TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (12, 59, DENSITY_UNITS, YELLOW, BLACK);
TTY.PUT (13, 1, "Specific heat of surrounding fluid           = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, SPECIFIC_HEAT, 4, 3);
TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (13, 59, SPECIFIC_HEAT_UNITS, YELLOW, BLACK);
TTY.PUT (14, 1, "Thermal conductivity of material, k          = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, K, 4, 3);
TTY.PUT (14, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (14, 59, K_UNITS, YELLOW, BLACK);
TTY.PUT (15, 1, "Thermal conductivity of surrounding fluid, k = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, K_FLUID, 4, 3);
TTY.PUT (15, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (15, 59, K_UNITS, YELLOW, BLACK);
TTY.PUT (16, 1, "Kinematic viscosity of surrounding fluid     = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, NU, 4, 3);
TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (16, 59, NU_UNITS, YELLOW, BLACK);
TTY.PUT (17, 1, "Ambient Temperature                          = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (17, 59, T_UNITS, YELLOW, BLACK);
TTY.PUT (18, 1, "Wall Temperature                             = ",
YELLOW, BLACK);
PUT (NUMBER_OUT, T_WALL, 4, 3);
TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
TTY.PUT (18, 59, T_UNITS, YELLOW, BLACK);
TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
```

```
    TTY.GET (PAUSE, CHAR);
    FINOPT_PICTURES.OUTPUT_CONT_MSG;
    TTY.PUT ( 6, 35, " Outputs ", BRIGHT_WHITE, GREEN);
    TTY.PUT ( 8, 1, "Heat transferred away by the fins, q         = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, Q, 4, 3);
    TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT ( 8, 59, Q_UNITS, YELLOW, BLACK);
    TTY.PUT ( 9, 1, "Spacing between fins                         = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, SPACING, 4, 3);
    TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT ( 9, 59, SPACING_UNITS, YELLOW, BLACK);
    TTY.PUT (10, 1, "Number of fins                               = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, NUM_FINS, 4, 3);
    TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT (10, 59, NUM_FINS_UNITS, YELLOW, BLACK);
    TTY.PUT (11, 1, "The fin efficiency                           = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
    TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT (12, 1, "The temperature at the tip of the fins       = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, T_TIP, 4, 3);
    TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
    TTY.PUT (13, 1, "Channel Rayleigh number                      = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, RAYLEIGH_CHANNEL, 4, 3);
    TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT (14, 1, "Channel Nusselt number                       = ",
    YELLOW, BLACK);
    PUT (NUMBER_OUT, NUSSELT_CHANNEL, 4, 3);
    TTY.PUT (14, 48, NUMBER_OUT, YELLOW, BLACK);
    TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
    TTY.GET (PAUSE, CHAR);

end MULTIPLE_MAX_FIN;

procedure MULTIPLE_MAX_Q(UNITS                       : in INTEGER;
                         CONVERT_DIST                : in FLOAT;
                         CONVERT_TEMP                : in FLOAT;
                         G_C                         : in FLOAT;
                         GRAVITY                     : in FLOAT;
                         WALL_LENGTH                 : in out FLOAT;
                         WALL_LENGTH_UNITS           : in STRING;
                         WALL_WIDTH                  : in out FLOAT;
                         WALL_WIDTH_UNITS            : in STRING;
                         LENGTH                      : in out FLOAT;
                         LENGTH_UNITS                : in STRING;
                         HEIGHT                      : in out FLOAT;
                         HEIGHT_UNITS                : in STRING;
                         WIDTH                       : in out FLOAT;
                         WIDTH_UNITS                 : in STRING;
                         SPACING                     : in out FLOAT;
```

```
                            SPACING_UNITS             : in STRING;
                            NUM_FINS                  : in out FLOAT;
                            NUM_FINS_UNITS            : in STRING;
                            DENSITY                   : in out FLOAT;
                            DENSITY_UNITS             : in STRING;
                            SPECIFIC_HEAT             : in out FLOAT;
                            SPECIFIC_HEAT_UNITS       : in STRING;
                            K                         : in out FLOAT;
                            K_FLUID                   : in out FLOAT;
                            K_UNITS                   : in STRING;
                            NU                        : in out FLOAT;
                            NU_UNITS                  : in STRING;
                            T_AMBIENT                 : in out FLOAT;
                            T_WALL                    : in out FLOAT;
                            T_UNITS                   : in STRING;
                            Q                         : in out FLOAT;
                            Q_UNITS                   : in STRING) is

      NUMBER_OUT                                      : STRING(1..10);

      CHAR                                            : CHARACTER;

      PAUSE, NUM_FINS_INT                             : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP, T_AVG, BETA, MU,
      RAYLEIGH_CHANNEL, NUSSELT_CHANNEL, H,
      AREA_BASE, AREA_FIN, AREA_TOTAL, P              : FLOAT;

   begin

-------------------------------------------------------------------------
--                          Inputs                                     --
-------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(WALL_LENGTH, "Length of the fin placement area", 32,
      WALL_LENGTH_UNITS, 2, 14);
      GET_INPUT(WALL_WIDTH, "Width of the fin placement area", 31,
      WALL_WIDTH_UNITS, 2, 15);
      GET_INPUT(LENGTH, "Length of each fin", 18, LENGTH_UNITS, 2, 16);
      GET_INPUT(HEIGHT, "Height of each fin", 18, HEIGHT_UNITS, 2, 17);
      GET_INPUT(WIDTH, "Width of each fin", 17, WIDTH_UNITS, 2, 18);
      if (UNITS = 2) then
         GET_INPUT(DENSITY, "Density of surrounding fluid", 28,
         DENSITY_UNITS, 8, 19);
      else
         GET_INPUT(DENSITY, "Density of surrounding fluid", 28,
         DENSITY_UNITS, 6, 19);
      end if;
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);
      FINOPT_PICTURES.INPUT_CONT_MSG;
      if (UNITS = 2) then
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 15, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 17, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 6, 17);
      else
         GET_INPUT(SPECIFIC_HEAT, "Specific heat of surrounding fluid",
         34, SPECIFIC_HEAT_UNITS, 12, 14);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 15);
         GET_INPUT(K_FLUID,
         "Thermal conductivity of surrounding fluid, k", 44,
         K_UNITS, 11, 16);
         GET_INPUT(NU, "Kinematic viscosity of surrounding fluid",
         40, NU_UNITS, 5, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19, T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16, T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--   Calculations (Assume Tip is Insulated) and Length >> Width       --
------------------------------------------------------------------------
      T_AVG := (T_WALL+T_AMBIENT)/2.0;
      BETA := 1.0/(T_AVG+CONVERT_TEMP);
      DELTA_T := T_WALL-T_AMBIENT;
      MU := (NU*DENSITY)/G_C;
      P := ((DENSITY**2)*GRAVITY*BETA*SPECIFIC_HEAT*DELTA_T)
      /(MU*(LENGTH/CONVERT_DIST)*K_FLUID);
      SPACING := CONVERT_DIST*(2.714/(P**(0.25)));
      NUM_FINS := (WALL_WIDTH-WIDTH)/(SPACING+WIDTH);
      NUM_FINS := NUM_FINS-0.49999999999;
      NUM_FINS_INT := INTEGER(NUM_FINS);
      NUM_FINS_INT := NUM_FINS_INT+1;
      NUM_FINS := FLOAT(NUM_FINS_INT);
      RAYLEIGH_CHANNEL := ((DENSITY**2)*GRAVITY*BETA*SPECIFIC_HEAT
      *((SPACING/CONVERT_DIST)**4)*DELTA_T)/(MU*(LENGTH/CONVERT_DIST)
      *K_FLUID);
      NUSSELT_CHANNEL := ((576.0/(RAYLEIGH_CHANNEL**2))
      +(2.873/SQRT(RAYLEIGH_CHANNEL)))**(-0.5);
      H := (NUSSELT_CHANNEL*K_FLUID)/(SPACING/CONVERT_DIST);
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      AREA_BASE :=
((WALL_WIDTH/CONVERT_DIST)*(WALL_LENGTH/CONVERT_DIST))
      -(NUM_FINS*(LENGTH/CONVERT_DIST)*(WIDTH/CONVERT_DIST));
      AREA_FIN := NUM_FINS*(2.0*(HEIGHT/CONVERT_DIST)
      *(LENGTH/CONVERT_DIST));
      AREA_TOTAL := AREA_BASE+(EFFICIENCY*AREA_FIN);
      Q := H*AREA_TOTAL*DELTA_T;
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));
```

```
----------------------------------------------------------------------
--                          Outputs                                 --
----------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Length of the fin placement area             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WALL_LENGTH, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, WALL_LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Width of the fin placement area              = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WALL_WIDTH, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, WALL_WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Length of each fin                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, LENGTH, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Height of each fin                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Width of each fin                            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WIDTH, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT (12, 1, "Density of surrounding fluid                 = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, DENSITY, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, DENSITY_UNITS, YELLOW, BLACK);
      TTY.PUT (13, 1, "Specific heat of surrounding fluid           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, SPECIFIC_HEAT, 4, 3);
      TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (13, 59, SPECIFIC_HEAT_UNITS, YELLOW, BLACK);
      TTY.PUT (14, 1, "Thermal conductivity of material, k          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT (14, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (14, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (15, 1, "Thermal conductivity of surrounding fluid, k = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K_FLUID, 4, 3);
      TTY.PUT (15, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (15, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (16, 1, "Kinematic viscosity of surrounding fluid     = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, NU, 4, 3);
      TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (16, 59, NU_UNITS, YELLOW, BLACK);
      TTY.PUT (17, 1, "Ambient Temperature                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (17, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (18, 1, "Wall Temperature                             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (18, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);
      FINOPT_PICTURES.OUTPUT_CONT_MSG;
      TTY.PUT ( 6, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 8, 1, "Heat transferred away by the fins, q         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Spacing between fins                         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, SPACING, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, SPACING_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Number of fins                               = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, NUM_FINS, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, NUM_FINS_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "The fin efficiency                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 1, "The temperature at the tip of the fins       = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (13, 1, "Channel Rayleigh number                      = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, RAYLEIGH_CHANNEL, 4, 3);
      TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (14, 1, "Channel Nusselt number                       = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, NUSSELT_CHANNEL, 4, 3);
      TTY.PUT (14, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end MULTIPLE_MAX_Q;

end FINOPT_MULTIPLE;
```

```
-- Title         : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--               :             A COMPUTER OPTIMIZATION
-- Author        : John Reynold Gensure
-- Date          : June 1992

package FINOPT_PICTURES is

   procedure THESIS_MSG;

   procedure FINOPT_MSG;

   procedure INPUT_MSG;

   procedure INPUT_CONT_MSG;

   procedure OUTPUT_MSG;

   procedure OUTPUT_CONT_MSG;

   procedure EXIT_MSG;

end FINOPT_PICTURES;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :               A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    COMMON_DISPLAY_TYPES, TTY, CURSOR;

use     COMMON_DISPLAY_TYPES;

package body FINOPT_PICTURES is

   procedure THESIS_MSG is

      PAUSE                                                 : INTEGER;

      CHAR                                                  : CHARACTER;

   begin
      CURSOR.INHIBIT;
      TTY.CLEAR_SCREEN;
      TTY.PUT  (2, 28, "NAVAL POSTGRADUATE SCHOOL", YELLOW, BLACK);
      TTY.PUT  (4, 31, "Monterey, California", YELLOW, BLACK);
      TTY.PUT  (6, 37, "THESIS", YELLOW, BLACK);
      TTY.PUT  (8, 16, "
",
      YELLOW, RED);
      TTY.PUT ( 9, 16, "          EXTENDED SURFACE HEAT SINKS
",
      YELLOW, RED);
      TTY.PUT (10, 16, "           FOR ELECTRONIC COMPONENTS:
",
      YELLOW, RED);
      TTY.PUT (11, 16, "            A COMPUTER OPTIMIZATION
",
      YELLOW, RED);
      TTY.PUT (12, 16, "
",
      YELLOW, RED);
      TTY.PUT (13, 16, "                       by
",
      YELLOW, RED);
      TTY.PUT (14, 16, "
",
      YELLOW, RED);
      TTY.PUT (15, 16, "              John Reynold Gensure
",
      YELLOW, RED);
      TTY.PUT (16, 16, "
",
      YELLOW, RED);
      TTY.PUT (17, 16, "                   June 1992
",
      YELLOW, RED);
      TTY.PUT (18, 16, "
",
      YELLOW, RED);
      TTY.PUT (19, 16, "  Thesis Advisor:               Allan D. Kraus
",
      YELLOW, RED);
      TTY.PUT (20, 16, "
",
      YELLOW, RED);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end THESIS_MSG;

   procedure FINOPT_MSG is

      PAUSE                                             : INTEGER;

      CHAR                                              : CHARACTER;

   begin
      TTY.CLEAR_SCREEN;
      TTY.PUT (4, 34, "Welcome To", GREEN, BLACK);
      TTY.PUT (8, 18, "    ", YELLOW, GREEN);
      TTY.PUT (8, 24, " ", YELLOW, GREEN);
      TTY.PUT (8, 27, " ", YELLOW, GREEN);
      TTY.PUT (8, 31, " ", YELLOW, GREEN);
      TTY.PUT (8, 34, "     ", YELLOW, GREEN);
      TTY.PUT (8, 41, "     ", YELLOW, GREEN);
      TTY.PUT (8, 48, "     ", YELLOW, GREEN);
      TTY.PUT (8, 55, " ", YELLOW, GREEN);
      TTY.PUT (8, 58, " ", YELLOW, GREEN);
      TTY.PUT (8, 61, " ", YELLOW, GREEN);
      TTY.PUT (9, 18, " ", YELLOW, GREEN);
      TTY.PUT (9, 24, " ", YELLOW, GREEN);
      TTY.PUT (9, 27, "  ", YELLOW, GREEN);
      TTY.PUT (9, 31, " ", YELLOW, GREEN);
      TTY.PUT (9, 34, " ", YELLOW, GREEN);
      TTY.PUT (9, 38, " ", YELLOW, GREEN);
      TTY.PUT (9, 41, " ", YELLOW, GREEN);
      TTY.PUT (9, 45, " ", YELLOW, GREEN);
      TTY.PUT (9, 50, " ", YELLOW, GREEN);
      TTY.PUT (9, 55, " ", YELLOW, GREEN);
      TTY.PUT (9, 58, " ", YELLOW, GREEN);
      TTY.PUT (9, 61, " ", YELLOW, GREEN);
      TTY.PUT (10, 18, "    ", YELLOW, GREEN);
      TTY.PUT (10, 24, " ", YELLOW, GREEN);
      TTY.PUT (10, 27, " ", YELLOW, GREEN);
      TTY.PUT (10, 29, " ", YELLOW, GREEN);
      TTY.PUT (10, 31, " ", YELLOW, GREEN);
      TTY.PUT (10, 34, " ", YELLOW, GREEN);
      TTY.PUT (10, 38, " ", YELLOW, GREEN);
      TTY.PUT (10, 41, "     ", YELLOW, GREEN);
      TTY.PUT (10, 50, " ", YELLOW, GREEN);
      TTY.PUT (10, 55, " ", YELLOW, GREEN);
      TTY.PUT (10, 58, " ", YELLOW, GREEN);
      TTY.PUT (10, 61, " ", YELLOW, GREEN);
      TTY.PUT (11, 18, " ", YELLOW, GREEN);
      TTY.PUT (11, 24, " ", YELLOW, GREEN);
   TTY.PUT (11, 27, " ", YELLOW, GREEN);
   TTY.PUT (11, 30, "  ", YELLOW, GREEN);
   TTY.PUT (11, 34, " ", YELLOW, GREEN);
   TTY.PUT (11, 38, " ", YELLOW, GREEN);
   TTY.PUT (11, 41, " ", YELLOW, GREEN);
   TTY.PUT (11, 50, " ", YELLOW, GREEN);
   TTY.PUT (12, 18, " ", YELLOW, GREEN);
   TTY.PUT (12, 24, " ", YELLOW, GREEN);
   TTY.PUT (12, 27, " ", YELLOW, GREEN);
   TTY.PUT (12, 31, " ", YELLOW, GREEN);
   TTY.PUT (12, 34, "     ", YELLOW, GREEN);
   TTY.PUT (12, 41, " ", YELLOW, GREEN);
   TTY.PUT (12, 50, " ", YELLOW, GREEN);
   TTY.PUT (12, 55, " ", YELLOW, GREEN);
   TTY.PUT (12, 58, " ", YELLOW, GREEN);
   TTY.PUT (12, 61, " ", YELLOW, GREEN);
   TTY.PUT (17, 26, "Version 1.0 dated June 1992", GREEN, BLACK);
   TTY.PUT (19, 24, "Written by John Reynold Gensure", GREEN, BLACK);
   TTY.PUT (23, 26, "  Press any key to continue ", BLUE, CYAN);
   TTY.GET (PAUSE, CHAR);

end FINOPT_MSG;

procedure INPUT_MSG is

begin
   TTY.CLEAR_SCREEN;
   TTY.PUT ( 1, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT ( 2, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT ( 3, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 3, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 4, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 4, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 5, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 5, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 6, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 6, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 7, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 7, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 8, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 8, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 9, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 9, 58, "   ", YELLOW, CYAN);
   TTY.PUT (10, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT (11, 19,
   "                                          ",  YELLOW, CYAN);
   TTY.PUT ( 3, 22, "                                    ",
   YELLOW, RED);
   TTY.PUT ( 4, 22, "          Required Inputs           ",
   BRIGHT_WHITE, RED);
   TTY.PUT ( 5, 22, "                                    ",
   YELLOW, RED);
   TTY.PUT ( 6, 22, "  Press enter to choose default or  ",
   YELLOW, RED);
   TTY.PUT ( 7, 22, "  any other key to input new value. ",
   YELLOW, RED);
   TTY.PUT ( 6, 22, "  All values must be inputted as    ",
   YELLOW, RED);
   TTY.PUT ( 7, 22, "  floats. Examples: 5.0 or 2.0E-3   ",
   YELLOW, RED);
   TTY.PUT ( 8, 22, "     Do not input 0.8 as .8 !!!     ",
   BRIGHT_WHITE, RED);
   TTY.PUT ( 9, 22, "                                    ",
   YELLOW, RED);

end INPUT_MSG;

procedure INPUT_CONT_MSG is

begin
   TTY.CLEAR_SCREEN;
   TTY.PUT ( 1, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT ( 2, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT ( 3, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 3, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 4, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 4, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 5, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 5, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 6, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 6, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 7, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 7, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 8, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 8, 58, "   ", YELLOW, CYAN);
   TTY.PUT ( 9, 19, "   ", YELLOW, CYAN);
   TTY.PUT ( 9, 58, "   ", YELLOW, CYAN);
   TTY.PUT (10, 19,
   "                                          ", YELLOW, CYAN);
   TTY.PUT (11, 19,
   "                                          ",  YELLOW, CYAN);
   TTY.PUT ( 3, 22, "                                    ",
   YELLOW, RED);
   TTY.PUT ( 4, 22, "     Required Inputs Continued      ",
   BRIGHT_WHITE, RED);
   TTY.PUT ( 5, 22, "                                    ",
   YELLOW, RED);
   TTY.PUT ( 6, 22, "  Press enter to choose default or  ",
   YELLOW, RED);
   TTY.PUT ( 7, 22, "  any other key to input new value. ",
   YELLOW, RED);
   TTY.PUT ( 6, 22, "  All values must be inputted as    ",
   YELLOW, RED);
   TTY.PUT ( 7, 22, "  floats. Examples: 5.0 or 2.0E-3   ",
   YELLOW, RED);
   TTY.PUT ( 8, 22, "     Do not input 0.8 as .8 !!!     ",
   BRIGHT_WHITE, RED);
```

```
      TTY.PUT ( 9, 22, "                                    ",
      YELLOW, RED);

   end INPUT_CONT_MSG;

   procedure OUTPUT_MSG is

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT ( 1, 26, "                             ", YELLOW, CYAN);
      TTY.PUT ( 2, 26, "  ", YELLOW, CYAN);
      TTY.PUT ( 2, 53, "  ", YELLOW, CYAN);
      TTY.PUT ( 3, 26, "                             ", YELLOW, CYAN);
      TTY.PUT ( 2, 28, "    Inputs => Outputs    ", BRIGHT_WHITE, RED);

   end OUTPUT_MSG;

   procedure OUTPUT_CONT_MSG is

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT ( 1, 26, "                             ", YELLOW, CYAN);
      TTY.PUT ( 2, 26, "  ", YELLOW, CYAN);
      TTY.PUT ( 2, 53, "  ", YELLOW, CYAN);
      TTY.PUT ( 3, 26, "  ", YELLOW, CYAN);
      TTY.PUT ( 3, 53, "  ", YELLOW, CYAN);
      TTY.PUT ( 4, 26, "                             ", YELLOW, CYAN);
      TTY.PUT ( 2, 28, "    Inputs => Outputs    ", BRIGHT_WHITE, RED);
      TTY.PUT ( 3, 28, "        Continued        ", BRIGHT_WHITE, RED);

   end OUTPUT_CONT_MSG;

   procedure EXIT_MSG is

   begin

      TTY.CLEAR_SCREEN;
      TTY.PUT (11, 18, "   ", YELLOW, CYAN);
      TTY.PUT (11, 58, "   ", YELLOW, CYAN);
      TTY.PUT (12, 18, "   ", YELLOW, CYAN);
      TTY.PUT (12, 58, "   ", YELLOW, CYAN);
      TTY.PUT (13, 18, "   ", YELLOW, CYAN);
      TTY.PUT (13, 58, "   ", YELLOW, CYAN);
      TTY.PUT ( 9, 18, "                                           ",
      YELLOW, CYAN);
      TTY.PUT (10, 18, "                                           ",
      YELLOW, CYAN);
      TTY.PUT (14, 18, "                                           ",
      YELLOW, CYAN);
      TTY.PUT (15, 18, "                                           ",
      YELLOW, CYAN);
      TTY.PUT (11, 21, "                                     ", YELLOW,
RED);
```

```
      TTY.PUT (12, 21, "   Thank you for using FINOPT !!!    ", YELLOW,
RED);
      TTY.PUT (13, 21, "                                     ", YELLOW,
RED);

   end EXIT_MSG;

end FINOPT_PICTURES;
```

```
-- Title        : EXTENDED SURFACE HEAT SINKS FOR ELECTRONIC COMPONENTS:
--              :               A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

package FINOPT_SINGLE is

   procedure CYLINDRICAL_NO_OPT(UNITS                    : in INTEGER;
                                CONVERT_DIST             : in FLOAT;
                                DIAMETER                 : in out FLOAT;
                                DIAMETER_UNITS           : in STRING;
                                HEIGHT                   : in out FLOAT;
                                HEIGHT_UNITS             : in STRING;
                                H                        : in out FLOAT;
                                H_UNITS                  : in STRING;
                                K                        : in out FLOAT;
                                K_UNITS                  : in STRING;
                                T_AMBIENT                : in out FLOAT;
                                T_WALL                   : in out FLOAT;
                                T_UNITS                  : in STRING;
                                Q                        : in out FLOAT;
                                Q_UNITS                  : in STRING);

   procedure CYLINDRICAL_GIVEN_VOL(UNITS                    : in
INTEGER;
                                   CONVERT_DIST             : in FLOAT;
                                   VOLUME                   : in out
FLOAT;
                                   VOLUME_UNITS             : in STRING;
                                   DIAMETER                 : in out
FLOAT;
                                   DIAMETER_UNITS           : in STRING;
                                   HEIGHT                   : in out
FLOAT;
                                   HEIGHT_UNITS             : in STRING;
                                   H                        : in out
FLOAT;
                                   H_UNITS                  : in STRING;
                                   K                        : in out
FLOAT;
                                   K_UNITS                  : in STRING;
                                   T_AMBIENT                : in out
FLOAT;
                                   T_WALL                   : in out
FLOAT;
                                   T_UNITS                  : in STRING;
                                   Q                        : in out
FLOAT;
                                   Q_UNITS                  : in
STRING);

   procedure CYLINDRICAL_GIVEN_Q(UNITS                    : in INTEGER;
                                 CONVERT_DIST             : in FLOAT;
                                 DIAMETER                 : in out
FLOAT;
                                 DIAMETER_UNITS           : in STRING;
                                 HEIGHT                   : in out
FLOAT;
                                 HEIGHT_UNITS             : in STRING;
                                 H                        : in out
FLOAT;
                                 H_UNITS                  : in STRING;
                                 K                        : in out
FLOAT;
                                 K_UNITS                  : in STRING;
                                 T_AMBIENT                : in out
FLOAT;
                                 T_WALL                   : in out
FLOAT;
                                 T_UNITS                  : in STRING;
                                 Q                        : in out
FLOAT;
                                 Q_UNITS                  : in STRING);

   procedure RECTANGULAR_NO_OPT(UNITS                    : in INTEGER;
                                CONVERT_DIST             : in FLOAT;
                                LENGTH                   : in out FLOAT;
                                LENGTH_UNITS             : in STRING;
                                HEIGHT                   : in out FLOAT;
                                HEIGHT_UNITS             : in STRING;
                                WIDTH                    : in out FLOAT;
                                WIDTH_UNITS              : in STRING;
                                H                        : in out FLOAT;
                                H_UNITS                  : in STRING;
                                K                        : in out FLOAT;
                                K_UNITS                  : in STRING;
                                T_AMBIENT                : in out FLOAT;
                                T_WALL                   : in out FLOAT;
                                T_UNITS                  : in STRING;
                                Q                        : in out FLOAT;
                                Q_UNITS                  : in STRING);

   procedure RECTANGULAR_GIVEN_VOL(UNITS                    : in
INTEGER;
                                   CONVERT_DIST             : in FLOAT;
                                   VOLUME                   : in out
FLOAT;
                                   VOLUME_UNITS             : in STRING;
                                   LENGTH                   : in out
FLOAT;
                                   LENGTH_UNITS             : in STRING;
                                   HEIGHT                   : in out
FLOAT;
                                   HEIGHT_UNITS             : in STRING;
                                   WIDTH                    : in out
FLOAT;
                                   WIDTH_UNITS              : in STRING;
                                   H                        : in out
FLOAT;
                                   H_UNITS                  : in STRING;
                                   K                        : in out
FLOAT;
                                   K_UNITS                  : in STRING;
                                   T_AMBIENT                : in out
FLOAT;
                                   T_WALL                   : in out
FLOAT;
                                   T_UNITS                  : in STRING;
                                   Q                        : in out
FLOAT;
                                   Q_UNITS                  : in
STRING);

   procedure RECTANGULAR_GIVEN_Q(UNITS                    : in INTEGER;
                                 CONVERT_DIST             : in FLOAT;
                                 LENGTH                   : in out
FLOAT;
                                 LENGTH_UNITS             : in STRING;
                                 HEIGHT                   : in out
FLOAT;
                                 HEIGHT_UNITS             : in STRING;
                                 WIDTH                    : in out
FLOAT;
                                 WIDTH_UNITS              : in STRING;
                                 H                        : in out
FLOAT;
                                 H_UNITS                  : in STRING;
                                 K                        : in out
FLOAT;
                                 K_UNITS                  : in STRING;
                                 T_AMBIENT                : in out
FLOAT;
                                 T_WALL                   : in out
FLOAT;
                                 T_UNITS                  : in STRING;
                                 Q                        : in out
FLOAT;
                                 Q_UNITS                  : in STRING);

end FINOPT_SINGLE;
```

```
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--              :              A COMPUTER OPTIMIZATION
-- Author       : John Reynold Gensure
-- Date         : June 1992

with    TEXT_IO, COMMON_DISPLAY_TYPES, TTY, CURSOR, FINOPT_COMMON,
        GENERIC_ELEMENTARY_FUNCTIONS, FINOPT_PICTURES;

use     TEXT_IO, COMMON_DISPLAY_TYPES, FINOPT_COMMON;

package body FINOPT_SINGLE is

   package FLOAT_INOUT is new FLOAT_IO(FLOAT);
   package MY_ELEMENTARY_FUNCTIONS is
           new GENERIC_ELEMENTARY_FUNCTIONS(FLOAT);
   use FLOAT_INOUT, MY_ELEMENTARY_FUNCTIONS;

   procedure CYLINDRICAL_NO_OPT(UNITS                    : in INTEGER;
                                CONVERT_DIST             : in FLOAT;
                                DIAMETER                 : in out FLOAT;
                                DIAMETER_UNITS           : in STRING;
                                HEIGHT                   : in out FLOAT;
                                HEIGHT_UNITS             : in STRING;
                                H                        : in out FLOAT;
                                H_UNITS                  : in STRING;
                                K                        : in out FLOAT;
                                K_UNITS                  : in STRING;
                                T_AMBIENT                : in out FLOAT;
                                T_WALL                   : in out FLOAT;
                                T_UNITS                  : in STRING;
                                Q                        : in out FLOAT;
                                Q_UNITS                  : in STRING) is

      NUMBER_OUT                                         :
STRING(1..10);

      CHAR                                               : CHARACTER;

      PAUSE                                              : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP                                     : FLOAT;

      PI  : constant :=
3.14159_26535_89793_23846_26433_83279_50288_41972 ;

   begin

------------------------------------------------------------------------
--                          Inputs                                    --
------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(DIAMETER, "Diameter of the cylindrical spine", 33,
      DIAMETER_UNITS, 2, 14);
      GET_INPUT(HEIGHT, "Height of the cylindrical spine", 31,
      HEIGHT_UNITS, 2, 15);
      if (UNITS = 2) then
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 17);
      else
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--              Calculations (Assume Tip is Insulated)                --
------------------------------------------------------------------------
      PERIMETER := PI*DIAMETER/CONVERT_DIST;
      AREA := (PI*((DIAMETER/CONVERT_DIST)**2))/4.0;
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

------------------------------------------------------------------------
--                         Outputs                                    --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Diameter of the cylindrical spine          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, DIAMETER, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, DIAMETER_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Height of the cylindrical spine            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Convection heat transfer coefficient, h    = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Thermal conductivity of material, k        = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Ambient Temperature                        = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (12, 1, "Wall Temperature                            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (14, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT (16, 1, "Heat transferred away by the fin, q         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (16, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT (17, 1, "The fin efficiency                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (18, 1, "The temperature at the tip                  = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (18, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end CYLINDRICAL_NO_OPT;

   procedure CYLINDRICAL_GIVEN_VOL(UNITS                    : in
INTEGER;
                                   CONVERT_DIST             : in FLOAT;
                                   VOLUME                   : in out
FLOAT;
                                   VOLUME_UNITS             : in STRING;
                                   DIAMETER                 : in out
FLOAT;
                                   DIAMETER_UNITS           : in STRING;
                                   HEIGHT                   : in out
FLOAT;
                                   HEIGHT_UNITS             : in STRING;
                                   H                        : in out
FLOAT;
                                   H_UNITS                  : in STRING;
                                   K                        : in out
FLOAT;
                                   K_UNITS                  : in STRING;
                                   T_AMBIENT                : in out
FLOAT;
                                   T_WALL                   : in out
FLOAT;
                                   T_UNITS                  : in STRING;
                                   Q                        : in out
FLOAT;
                                   Q_UNITS                  : in STRING)
is
```

```
      NUMBER_OUT                                            :
STRING(1..10);

      CHAR                                                  : CHARACTER;

      PAUSE                                                 : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP                                        : FLOAT;

      PI  : constant :=
3.14159_26535_89793_23846_26433_83279_50288_41972 ;

   begin

------------------------------------------------------------------------
--                          Inputs                                    --
------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(VOLUME, "Volume of the cylindrical spine", 31,
      VOLUME_UNITS, 4, 14);
      if (UNITS = 2) then
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 15);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 16);
      else
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 15);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 16);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 17);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 18);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--              Calculations (Assume Tip is Insulated)                --
------------------------------------------------------------------------
      DIAMETER := CONVERT_DIST*1.5031*(H/K*(VOLUME
      /CONVERT_DIST**3)**2)**(0.2);
      HEIGHT := CONVERT_DIST*0.5636*((VOLUME
      /CONVERT_DIST**3)*(K/H)**2)**(0.2);
      PERIMETER := PI*DIAMETER/CONVERT_DIST;
      AREA := (PI*((DIAMETER/CONVERT_DIST)**2))/4.0;
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));
```

```
------------------------------------------------------------------------
--                      Outputs                                       --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Volume of the cylindrical spine              = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, VOLUME, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, VOLUME_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Convection heat transfer coefficient, h      = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Thermal conductivity of material, k          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Ambient Temperature                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Wall Temperature                             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (13, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT (15, 1, "Optimum diameter of the cylindrical spine    = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, DIAMETER, 4, 3);
      TTY.PUT (15, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (15, 59, DIAMETER_UNITS, YELLOW, BLACK);
      TTY.PUT (16, 1, "Optimum height of the cylindrical spine      = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (16, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT (17, 1, "Heat transferred away by the fin, q          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (17, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT (18, 1, "The fin efficiency                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 1, "The temperature at the tip                   = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (19, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end CYLINDRICAL_GIVEN_VOL;

   procedure CYLINDRICAL_GIVEN_Q(UNITS                    : in INTEGER;
                                 CONVERT_DIST             : in FLOAT;
                                 DIAMETER                 : in out
FLOAT;
                                 DIAMETER_UNITS           : in STRING;
                                 HEIGHT                   : in out
FLOAT;
                                 HEIGHT_UNITS             : in STRING;
                                 H                        : in out
FLOAT;
                                 H_UNITS                  : in STRING;
                                 K                        : in out
FLOAT;
                                 K_UNITS                  : in STRING;
                                 T_AMBIENT                : in out
FLOAT;
                                 T_WALL                   : in out
FLOAT;
                                 T_UNITS                  : in STRING;
                                 Q                        : in out
FLOAT;
                                 Q_UNITS                  : in STRING)
is

      NUMBER_OUT                                          :
STRING(1..10);

      CHAR                                                : CHARACTER;

      PAUSE                                               : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP                                      : FLOAT;

      PI  : constant :=
3.14159_26535_89793_23846_26433_83279_50288_41972 ;

   begin

-----------------------------------------------------------------------
--                          Inputs                                   --
-----------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      if (UNITS = 2) then
         GET_INPUT(Q, "Heat transferred away by the fin, q", 35,
         Q_UNITS, 6, 14);
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 15);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 16);
      else
         GET_INPUT(Q, "Heat transferred away by the fin, q", 35,
         Q_UNITS, 1, 14);
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 15);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 16);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 17);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 18);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--              Calculations (Assume Tip is Insulated)                --
------------------------------------------------------------------------
      DIAMETER := CONVERT_DIST*0.9165*((Q**2)
      /(H*K*((T_WALL-T_AMBIENT)**2)))**(1.0/3.0);
      HEIGHT := CONVERT_DIST*0.4400*((Q*K)
      /((H**2)*(T_WALL-T_AMBIENT)))**(1.0/3.0);
      PERIMETER := PI*DIAMETER/CONVERT_DIST;
      AREA := (PI*((DIAMETER/CONVERT_DIST)**2))/4.0;
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

------------------------------------------------------------------------
--                       Outputs                                      --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Heat transferred away by the fin, q          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Convection heat transfer coefficient, h      = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Thermal conductivity of material, k          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Ambient Temperature                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Wall Temperature                             = ",
      YELLOW, BLACK);
```

```
        PUT (NUMBER_OUT, T_WALL, 4, 3);
        TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
        TTY.PUT (11, 59, T_UNITS, YELLOW, BLACK);
        TTY.PUT (13, 35, " Outputs ", BRIGHT_WHITE, GREEN);
        TTY.PUT (15, 1, "Optimum diameter of the cylindrical spine    = ",
        YELLOW, BLACK);
        PUT (NUMBER_OUT, DIAMETER, 4, 3);
        TTY.PUT (15, 48, NUMBER_OUT, YELLOW, BLACK);
        TTY.PUT (15, 59, DIAMETER_UNITS, YELLOW, BLACK);
        TTY.PUT (16, 1, "Optimum height of the cylindrical spine      = ",
        YELLOW, BLACK);
        PUT (NUMBER_OUT, HEIGHT, 4, 3);
        TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
        TTY.PUT (16, 59, HEIGHT_UNITS, YELLOW, BLACK);
        TTY.PUT (17, 1, "The fin efficiency                           = ",
        YELLOW, BLACK);
        PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
        TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
        TTY.PUT (18, 1, "The temperature at the tip                   = ",
        YELLOW, BLACK);
        PUT (NUMBER_OUT, T_TIP, 4, 3);
        TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
        TTY.PUT (18, 59, T_UNITS, YELLOW, BLACK);
        TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
        TTY.GET (PAUSE, CHAR);

     end CYLINDRICAL_GIVEN_Q;


     procedure RECTANGULAR_NO_OPT(UNITS                    : in INTEGER;
                                  CONVERT_DIST             : in FLOAT;
                                  LENGTH                   : in out FLOAT;
                                  LENGTH_UNITS             : in STRING;
                                  HEIGHT                   : in out FLOAT;
                                  HEIGHT_UNITS             : in STRING;
                                  WIDTH                    : in out FLOAT;
                                  WIDTH_UNITS              : in STRING;
                                  H                        : in out FLOAT;
                                  H_UNITS                  : in STRING;
                                  K                        : in out FLOAT;
                                  K_UNITS                  : in STRING;
                                  T_AMBIENT                : in out FLOAT;
                                  T_WALL                   : in out FLOAT;
                                  T_UNITS                  : in STRING;
                                  Q                        : in out FLOAT;
                                  Q_UNITS                  : in STRING) is

        NUMBER_OUT                                         :
   STRING(1..10);

        CHAR                                               : CHARACTER;

        PAUSE                                              : INTEGER;

        PERIMETER, AREA, M, EFFICIENCY,
        DELTA_T, T_TIP                                     : FLOAT;
   begin

------------------------------------------------------------------------
--                            Inputs                                  --
------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(LENGTH, "Length of the rectangular fin", 29,
      LENGTH_UNITS, 2, 14);
      GET_INPUT(HEIGHT, "Height of the rectangular fin", 29,
      HEIGHT_UNITS, 2, 15);
      GET_INPUT(WIDTH, "Width of the rectangular fin", 28,
      WIDTH_UNITS, 2, 16);
      if (UNITS = 2) then
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 17);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 18);
      else
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 17);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 18);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 19);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 20);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--    Calculations (Assume Tip is Insulated) and Length >> Width      --
------------------------------------------------------------------------
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

------------------------------------------------------------------------
--                         Outputs                                    --
------------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Length of the rectangular fin              = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, LENGTH, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Height of the rectangular fin              = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Width of the rectangular fin                 = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WIDTH, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Convection heat transfer coefficient, h      = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Thermal conductivity of material, k          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (12, 1, "Ambient Temperature                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (13, 1, "Wall Temperature                             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (13, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (13, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (15, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT (17, 1, "Heat transferred away by the fin, q          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (17, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT (18, 1, "The fin efficiency                           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 1, "The temperature at the tip                   = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (19, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end RECTANGULAR_NO_OPT;

   procedure RECTANGULAR_GIVEN_VOL(UNITS                    : in
INTEGER;
                                   CONVERT_DIST             : in FLOAT;
                                   VOLUME                   : in out
FLOAT;
                                   VOLUME_UNITS             : in STRING;
                                   LENGTH                   : in out
FLOAT;
                                   LENGTH_UNITS             : in STRING;
```

```
                                    HEIGHT                   : in out
FLOAT;
                                    HEIGHT_UNITS             : in STRING;
                                    WIDTH                    : in out
FLOAT;
                                    WIDTH_UNITS              : in STRING;
                                    H                        : in out
FLOAT;
                                    H_UNITS                  : in STRING;
                                    K                        : in out
FLOAT;
                                    K_UNITS                  : in STRING;
                                    T_AMBIENT                : in out
FLOAT;
                                    T_WALL                   : in out
FLOAT;
                                    T_UNITS                  : in STRING;
                                    Q                        : in out
FLOAT;
                                    Q_UNITS                  : in STRING)
is

      NUMBER_OUT                                             :
STRING(1..10);

      CHAR                                                   : CHARACTER;

      PAUSE                                                  : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP, AREA_PROFILE                           : FLOAT;

   begin

-------------------------------------------------------------------------
--                          Inputs                                     --
-------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      GET_INPUT(VOLUME, "Volume of the rectangular fin", 29,
      VOLUME_UNITS, 4, 14);
      GET_INPUT(LENGTH, "Length of the rectangular fin", 29,
      LENGTH_UNITS, 2, 15);
      if (UNITS = 2) then
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 17);
      else
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

-----------------------------------------------------------------------
--   Calculations (Assume Tip is Insulated) and Length >> Width      --
-----------------------------------------------------------------------
      AREA_PROFILE := (VOLUME/(CONVERT_DIST**3))
      /(LENGTH/CONVERT_DIST);
      WIDTH := CONVERT_DIST*0.9977
      *((AREA_PROFILE**2)*H/K)**(1.0/3.0);
      HEIGHT := CONVERT_DIST*1.0023
      *(AREA_PROFILE*K/H)**(1.0/3.0);
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

-----------------------------------------------------------------------
--                       Outputs                                     --
-----------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Volume of the rectangular fin               = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, VOLUME, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, VOLUME_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Length of the rectangular fin               = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, LENGTH, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Convection heat transfer coefficient, h     = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Thermal conductivity of material, k         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Ambient Temperature                         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (12, 1, "Wall Temperature                            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (14, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT (16, 1, "Optimum height of the rectangular fin          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (16, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT (17, 1, "Optimum width of the rectangular fin           = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WIDTH, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (17, 59, WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT (18, 1, "Heat transferred away by the fin, q            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (18, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT (19, 1, "The fin efficiency                             = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (19, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (20, 1, "The temperature at the tip                     = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (20, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (20, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end RECTANGULAR_GIVEN_VOL;

   procedure RECTANGULAR_GIVEN_Q(UNITS                    : in INTEGER;
                                 CONVERT_DIST             : in FLOAT;
                                 LENGTH                   : in out
FLOAT;
                                 LENGTH_UNITS             : in STRING;
                                 HEIGHT                   : in out
FLOAT;
                                 HEIGHT_UNITS             : in STRING;
                                 WIDTH                    : in out
FLOAT;
                                 WIDTH_UNITS              : in STRING;
                                 H                        : in out
FLOAT;
                                 H_UNITS                  : in STRING;
                                 K                        : in out
FLOAT;
                                 K_UNITS                  : in STRING;
                                 T_AMBIENT                : in out
FLOAT;
                                 T_WALL                   : in out
FLOAT;
                                 T_UNITS                  : in STRING;
                                 Q                        : in out
FLOAT;
```

```
                                 Q_UNITS                   : in STRING)
is

      NUMBER_OUT                                           :
STRING(1..10);

      CHAR                                                 : CHARACTER;

      PAUSE                                                : INTEGER;

      PERIMETER, AREA, M, EFFICIENCY,
      DELTA_T, T_TIP                                       : FLOAT;

   begin

------------------------------------------------------------------------
--                           Inputs                                   --
------------------------------------------------------------------------
      FINOPT_PICTURES.INPUT_MSG;
      if (UNITS = 2) then
         GET_INPUT(Q, "Heat transferred away by the fin, q", 35,
         Q_UNITS, 6, 14);
      else
         GET_INPUT(Q, "Heat transferred away by the fin, q", 35,
         Q_UNITS, 1, 14);
      end if;
      GET_INPUT(LENGTH, "Length of the rectangular fin", 29,
         LENGTH_UNITS, 2, 15);
      if (UNITS = 2) then
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 19, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 17, 17);
      else
         GET_INPUT(H, "Convection heat transfer coefficient, h", 39,
         H_UNITS, 13, 16);
         GET_INPUT(K, "Thermal conductivity of material, k", 35,
         K_UNITS, 11, 17);
      end if;
      GET_INPUT(T_AMBIENT, "Ambient Temperature", 19,
      T_UNITS, 5, 18);
      GET_INPUT(T_WALL, "Wall Temperature", 16,
      T_UNITS, 5, 19);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

------------------------------------------------------------------------
--     Calculations (Assume Tip is Insulated) and Length >> Width     --
------------------------------------------------------------------------
      WIDTH := CONVERT_DIST*(0.6321/(H*K))
      *(((Q/(LENGTH/CONVERT_DIST))/(T_WALL-T_AMBIENT))**2);
      HEIGHT := CONVERT_DIST*0.7978
      *(Q/(LENGTH/CONVERT_DIST))/(H*(T_WALL-T_AMBIENT));
      PERIMETER := 2.0*LENGTH/CONVERT_DIST;
      AREA := (WIDTH/CONVERT_DIST)*(LENGTH/CONVERT_DIST);
      M := SQRT((H*PERIMETER)/(K*AREA));
      DELTA_T := T_WALL-T_AMBIENT;
      Q := K*AREA*M*DELTA_T*TANH(M*HEIGHT/CONVERT_DIST);
      EFFICIENCY := (TANH(M*HEIGHT/CONVERT_DIST))
      /(M*HEIGHT/CONVERT_DIST);
      T_TIP := T_AMBIENT+(DELTA_T/COSH(M*HEIGHT/CONVERT_DIST));

-----------------------------------------------------------------------
--                       Outputs                                     --
-----------------------------------------------------------------------
      FINOPT_PICTURES.OUTPUT_MSG;
      TTY.PUT ( 5, 36, " Inputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT ( 7, 1, "Heat transferred away by the fin, q         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, Q, 4, 3);
      TTY.PUT ( 7, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 7, 59, Q_UNITS, YELLOW, BLACK);
      TTY.PUT ( 8, 1, "Length of the rectangular fin               = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, LENGTH, 4, 3);
      TTY.PUT ( 8, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 8, 59, LENGTH_UNITS, YELLOW, BLACK);
      TTY.PUT ( 9, 1, "Convection heat transfer coefficient, h     = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, H, 4, 3);
      TTY.PUT ( 9, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT ( 9, 59, H_UNITS, YELLOW, BLACK);
      TTY.PUT (10, 1, "Thermal conductivity of material, k         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, K, 4, 3);
      TTY.PUT (10, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (10, 59, K_UNITS, YELLOW, BLACK);
      TTY.PUT (11, 1, "Ambient Temperature                         = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_AMBIENT, 4, 3);
      TTY.PUT (11, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (11, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (12, 1, "Wall Temperature                            = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_WALL, 4, 3);
      TTY.PUT (12, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (12, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (14, 35, " Outputs ", BRIGHT_WHITE, GREEN);
      TTY.PUT (16, 1, "Optimum height of the rectangular fin       = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, HEIGHT, 4, 3);
      TTY.PUT (16, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (16, 59, HEIGHT_UNITS, YELLOW, BLACK);
      TTY.PUT (17, 1, "Optimum width of the rectangular fin        = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, WIDTH, 4, 3);
      TTY.PUT (17, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (17, 59, WIDTH_UNITS, YELLOW, BLACK);
      TTY.PUT (18, 1, "The fin efficiency                          = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, EFFICIENCY, 4, 3);
      TTY.PUT (18, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 1, "The temperature at the tip                   = ",
      YELLOW, BLACK);
      PUT (NUMBER_OUT, T_TIP, 4, 3);
      TTY.PUT (19, 48, NUMBER_OUT, YELLOW, BLACK);
      TTY.PUT (19, 59, T_UNITS, YELLOW, BLACK);
      TTY.PUT (23, 27, " Press any key to continue ", BLUE, CYAN);
      TTY.GET (PAUSE, CHAR);

   end RECTANGULAR_GIVEN_Q;

end FINOPT_SINGLE;
```

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